239 J

THE UNIVERSITY of TULSA

Department of Petroleum Engineering

Paraffin Deposition Prediction in Multiphase Flowlines and Wellbores Joint Industry Project

Fluid Characterization and Property Evaluation Final Report

Confidential

February, 1999

Acknowledgments

The University of Tulsa acknowledges Marathon Oil Company and DB Robinson for their efforts on characterizing and determining fluid properties on fluids from three wells: Mobil Oil Company's South Pelto Well No. 9-2, Shell Oil Company's Garden Banks 426 Well No. A-14 and Chevron Oil Company's Main Pass 299 Well No. B-4. Our thanks also go out to Jeff Creek at Chevron for converting the data presented in the quarterly reports to independent fluid and property evaluation reports.

Table of Contents

I. Introduction

This report presents all of the data determined in response to the contract awarded to Marathon Oil Company by The University of Tulsa Paraffin Deposition Joint Industry Project (JIP). The purpose of this work was to provide fluid property data on hydrocarbon fluids to be used in the JIP single phase and multiphase flow deposition tests. Required are:

1. Sample Conditioning and Physical Recombination for Recombined Oil 1, Recombined Oil 2, Recombined Condensate, Flow Loop Oil, and Flow Loop Condensate:

   For each recombined oil, restore separator gas and separator liquid by heating and pressurization back to 150°F. From specified gas-oil ratio, use the conditioned separator products to reconstitute the original reservoir fluid. Work includes separator fluid quality checks, compositional analysis including C_{30+} composition of recombined reservoir fluid, density measurements, and physical recombination.

   For each separator oil, check the stock tank oil for water content. Heat stock tank oil container walls and agitate fluid. Synthesize solution gas from supplied composition or liquefy natural gas if sample is provided. From specified gas-oil ratio, use stock tank oil and natural gas to reconstitute the flow loop fluids. Work includes compositional analysis including C_{30+} composition of reconstituted flow loop fluid, density of reservoir fluid at P_{ob}, synthesis or liquefaction of natural gas, and physical recombination.

   For Recombined Oil 1 and Recombined Condensate, reconstitute approximately 1 additional liter of reservoir fluid and ship to D.B. Robinson & Associates in Edmonton, Alberta Canada.

2. Constant Composition Expansion (CCE) Studies for Recombined Oil 1, Recombined Oil 2, Recombined Condensate, Flow Loop Oil, and Flow Loop Condensate:

   For each recombined fluid, measure phase volumes, phase densities (Anton-Paar "oscillating tube" densitometer), and liquid phase viscosities (capillary coil viscometer) at three pressures (the saturation pressure, 500 psia, and one intermediate pressure) for three temperatures each (40°F, reservoir temperature, and an intermediate temperature).

   For each flow loop fluid, measure phase volume fractions, phase densities, and liquid phase viscosities at five pressures (the saturation pressure, 500 psia, and three intermediate pressure) for three temperatures each (40°F, reservoir temperature, and an intermediate temperature).

3. Cloud Point Determinations for Recombined Oil 1, Recombined Oil 2, Flow Loop Oil, and Flow Loop Condensate:

   For each recombined oil, measure cloud point (wax appearance temperature [WAT]) and wax dissolution temperature (WDT) at five different pressures. One of two different techniques will be selected for these measurements based on results obtained by both techniques for one pressure (above saturation pressure). Filter plugging (10,000 psig pressure limit) measures cloud point under dynamic conditions. Scattering of Infrared energy (FTIR, 7,000 psi limit) measures the cloud point under static conditions.

   For each flow loop oil, measure WAT and WDT at 5 different pressures using high-pressure cloud point technique selected above.

2. Experimental Data

Separator and stock tank samples were taken from three wells: South Pelto 10 Well 9-2, Main Pass 299 Well B-4, and Garden Banks 426 Well A-14. The following field samples were taken from each well:

South Pelto 10 Well 9-2
(8) one liter cylinders of separator gas
(4) one liter cylinders of separator liquid
(2) five gallon DOT cans of stock tank oil

Main Pass 299 Well B-4
(5) one liter cylinders of separator gas
(2) one liter cylinders of separator liquid
(2) five gallon DOT cans of stock tank oil

Garden Banks 426 Well A-14
(16) 500 cc cylinders of separator gas
(6) 500 cc cylinders of separator liquid
(2) one gallon DOT cans of stock tank oil

A 43.8-liter cylinder containing a synthetic five-component gas blend representing The University of Tulsa's natural gas stream was prepared by Marathon Oil Company. This gas and liquid samples were recombined to make the reservoir and flow loop fluids studied in this work.

The experiments were performed by Marathon Petroleum Technology Company, Nenniger Engineering, and D.B. Robinson Associates. The data are organized by fluid in three sections included as appendices. Each appendix is a properties report for a particular fluid. Appendix 3.1 reports data measured on oil from Mobil's South Pelto 10 Field. Appendix 3.2 reports data measured on condensate from Shell's Garden Banks 426 Field. Appendix 3.3 reports data measured on oil from Chevron's Main Pass 299 Field. The order for which the data appear in each section is approximately the same order as prescribed in the proposal. Also attached, without the sections from the Quarterly reports, as Appendix 3.4 is the Final Report prepared by Marathon that was distributed and presented to participants at the April 1997 Advisory Board meeting.

3. Appendices

3.1. S. Pelto 10 Well 9-2 Fluid Characterization and Property Evaluation Study

3.2. Garden Banks 426 Well A-14 Reservoir Fluid Characterization and Property Evaluation Study

3.3. Main Pass 299 Well B-4 Fluid Characterization and Property Evaluation Study

3.4. Marathon's Fluid Characterization and Property Evaluation Final Report

Appendix 3.1: S. Pelto 10 Well 9-2 Fluid Characterization and Property Evaluation Study

3.1. Oil 1- South Pelto

On January 12, 1996, Weatherly Laboratories collected separator samples from Mobil Oil Company's South Pelto Well No. 9-2 for The University of Tulsa's JIP Recombined Oil No. 1 studies. Duplicate samples were collected resulting in a total of eight separator gas samples and four separator liquid samples. These samples, plus a five gallon can of stock tank oil, arrived at Marathon Oil Company's Petroleum Technology Center on January 19, 1996.

3.1.1. Separator Samples

As a quality check, the opening pressure of the separator gases and the bubble point pressure of the separator liquids were determined at ambient temperature. These results are presented in Table 3.1.1. One of the samples, separator gas Cylinder No. WL-142 appeared to have been compromised. Prior to taking any sample outage, each separator liquid cylinder was conditioned by being heated to 150°F and pressurized to 1500 psig. Each separator gas cylinder was also conditioned by being heated to 150°F.

Compositions were determined for all separator gases and liquids. The stock tank oil gravities from all produced samples are given in Table 3.1.2. The compositional results show that there is very good comparison between the duplicate gas and liquid samples. These data are presented in Tables 3.1.3 and 3.1.4. The composition of the separator liquid was also analyzed by using gas chromatography. The separator liquid compositions are reported through C_{30+} in Table 3.1.4. The mass percent values are measured. The properties of the individual C_{6+} fractions were not measured but rather estimated. The molecular weights of the C_6-C_{29} fractions are values reported by Katz and Firoozabadi[1] for general petroleum fractions. The specific gravity values for C_6-C_{30+} fractions are calculated using a constant Watson K factor of 11.87. The C_{30+} molecular weight and overall Watson K factor were calculated to match the measured molecular weight, measured by Freezing Point Depression, and the 60°F density value, measured by using a Paar-Mettler densitometer, for the stabilized liquid created from the separator liquid.

Figure 3.1.1 shows the equilibrium K values plotted for gas composition from Cylinder No. WL-256 and liquid composition from Cylinder No. WL-170. The K-value results indicate that the collected separator gases and liquids were in equilibrium at separator conditions.

3.1.2. Reservoir Fluid Properties

3.1.2.1. Recombination

Erratic production rates of gas and liquid as well as the production of free gas, solution gas, and gas lift gas were observed during previous South Pelto sampling operations. Upon conferring with The University of Tulsa personnel and Marathon management, it was decided that the separator products should be recombined to the static shut-in conditions of 3192 psig and 232°F obtained from a Well No. 9-2 pressure/temperature survey run on December 5, 1995.

---

[1] Katz, D. L. and Firoozabadi, A., "Predicting Phase Behavior of Condensate Crude-Oil Systems using Methane Interaction Coefficients", J. Pet. Tech., November 1978, pp. 1649 – 1655.

As stated in the proposal, the fluid in the PVT cell was expanded down to 506 psia where the equilibrate gas was pumped off to the densitometer. All remaining gas was then pumped out of the PVT cell until the 506 psia equilibrium oil was all that remained in the cell. The oil at this pressure was then pumped to the densitometer and the viscometer.

After the 506 psia measurements, another small portion of recombined reservoir fluid was charged to the PVT cell. This fluid was used to verify the bubble point pressure and obtain property data at the intermediate pressure of 1874 psia.

The CCE data along with the density and viscosity data are presented in Table 3.1.7. The density values denoted by an asterisk are measured. All other oil densities above bubble point are interpolated from relative volume data. All oil viscosities denoted by asterisk are measured. The oil viscosity at the bubble point pressure is linearly interpolated from the measured single-phase oil viscosity values.

3.1.2.4. Constant Composition Expansion Test @ 136°F

A portion of the reservoir fluid was charged to a high-pressure visual PVT cell and thermally equilibrated at 136°F. The fluid was then subjected to a constant composition expansion, CCE. During this expansion a bubble point pressure of 2895 psia was observed.

As stated in the above CCE at 232°F, an amount of fluid was also charged from the recombination cylinder to the densitometer and viscometer. Single-phase density and viscosity measurements were taken at various pressures at 136°F.

The fluid in the PVT cell was expanded down to 506 psia where the equilibrate gas was pumped off to the densitometer. All remaining gas was then pumped out of the PVT cell until the 506 psia equilibrate oil was all that remained in the cell. The oil at this pressure was then pumped to the densitometer and the viscometer.

After the 506 psia measurements, another small portion of recombined reservoir fluid was charged to the PVT cell. This fluid was used to verify the bubble point pressure and obtain property data at the intermediate pressure of 1722 psia.

The CCE data along with the density and viscosity data are presented in Table 3.1.8. The measured and interpolated values for density and viscosity were determined by the same techniques used at 232°F (Table 3.1.7).

3.1.2.5. Constant Composition Expansion Test @ 42°F

A portion of the reservoir fluid was charged to a high-pressure visual PVT cell at 136°F. The PVT cell and airbath were then cooled down to the requested temperature of 42°F while being agitated. The fluid was then subjected to a constant composition expansion, CCE. During this expansion a bubble point pressure of 2518 psia was observed.

The fluid in the PVT cell was expanded down to 506 psia. The equilibrate gas was pumped off to the densitometer. Prior to removing any oil, the PVT cell was never allowed to remain static. The 506 psia equilibrate oil was then pumped to the densitometer and the viscometer. The data obtained for density appears reliable with no apparent problems being observed. The pressure drop at various flow rates needed to calculate the viscosity at this pressure were erratic. Several runs were performed in order to get stabilized readings.

A small portion of recombined reservoir fluid was charged to the PVT cell. This fluid was used to verify the bubble point pressure and obtain property data at the intermediate pressure of

oil values. All oil densities and viscosities denoted by an asterisk were measured.

CCE, density, and viscosity data are presented in Table 3.1.13.

As stated in the scope of work, the fluid in the PVT cell was expanded down to 97 psia. At this pressure, some equilibrated gas was pumped off to the densitometer and then collected into a small high pressure cylinder for compositional analysis. This data may be found in Table 3.1.14. Then all remaining gas was pumped out of the PVT cell until the 97 psia equilibrated oil was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscosimeter, while maintaining constant temperature and pressure. All remaining oil at 97 psia was pumped out of the PVT cell and collected into a small high pressure cylinder for compositional analysis. This data may be also found in Table 3.1.14.

After the 97 psia measurements, subsequent samples of conditioned Flow Loop Oil were charged to the PVT cell. The bubble point of this fluid was verified each time, then property data at the intermediate pressures of 386 psia, 289 psia, and 184 psia were obtained. This data may also be found in Table 3.1.13.

3.1.3.3. Constant Composition Expansion @90°F

A portion of Flow Loop Oil, still conditioned at 1,500 psig and 140°F, was charged into a high-pressure visual PVT cell, contained within an air bath and thermally equilibrated at a temperature of 90°F. The fluid was then subjected to a CCE. During this expansion a bubble point pressure of 423 psia was observed.

As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscosimeter, both at 90°F. Single-phase density and viscosity measurements were taken at various pressures. The oil density and viscosity at the bubble point pressure was linearly interpolated from the measured single-phase oil values. All oil densities and viscosities denoted by an asterisk were measured.

CCE, density, and viscosity data are presented in Table 3.1.15.

The fluid in the PVT cell was then expanded down to 97 psia. At this pressure, some equilibrated gas was pumped off to the densitometer and then collected into a small high pressure cylinder for compositional analysis. This data may be found in Table 3.1.16. Then all remaining gas was pumped out of the PVT cell until the 97 psia equilibrated oil was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscosimeter, while maintaining constant temperature and pressure. All remaining oil at 97 psia was pumped out of the PVT cell and collected into a small high pressure cylinder for compositional analysis. This data may be found in Table 3.1.16.

After the 97 psia measurements, another sample of conditioned Flow Loop Oil was charged to the PVT cell. The bubble point of this fluid was verified, then property data at the intermediate pressure of 234 psia was obtained. This data may also be found in Table 3.1.16.

3.1.3.4. Constant Composition Expansion Test @40°F

A portion of Flow Loop Oil, still conditioned at 1,500 psig and 140°F, was charged into a high-pressure visual PVT cell, contained within an air bath and thermally equilibrated at a temperature of 40°F. The fluid was then subjected to a CCE. During this expansion a bubble point pressure of 309 psia was observed. The fluid in the PVT cell was expanded down to a final pressure of 97 psia.

temperature. The accuracy is clearly related to the to the rate of cooling and the homogeneity of the temperature in the experimental apparatus. The magnitude of the signal also depends on cooling rate in the DSC experiments for example. Clearly the best data are for the lowest reasonable cooling rates. The refer to Jim Tackett's (Marathon) work for Deepstar CTR 207 Final Report and Kathy Greenhill's Deepstar CTR 204 final report for more extensive explanation of the limitations and accuracy of the different techniques use to measure the WAT.

3.1.6. Wax Dissolution Determinations

Wax dissolution temperatures (WDT), the temperature when all of the wax dissolves when the sample is heated, were measured using the FTIR technique. The infrared scatter data obtained when the RRF sample was heated from 160°F to 44°F to 160°F at 0.3°F per minute is shown in Figure 3.1.3. The WAT and WDT points are labeled. (This curve was greatly amplified to obtain these values.) This curve represents "best" case data. The infrared scatter curves were not as well defined for some of the run conditions and differential techniques were used to locate the WAT and WDT points.

The WDT values are listed in Table 3.1.18. The average difference between WDT and WAT for all the run conditions was 14°F. All of the individual differences were between 10 and 17°F with the exception of a low value of 4°F and a high value of 28°F. These two values which are marked by a (*) in Table 3.1.18 appear to be outliers. Repeat runs were not made.

3.1.7. Solid Wax Determinations

Table 3.1.22 compares the data determined by Marathon and D.B. Robinson on solids collect from the flow loop oils at temperatures near 50°F.

3.1.7.1. Marathon Precipitation Experiments

The Marathon Oil Company made a set of equilibrium measurements to determine the composition and amount of solid wax from Recombined Oil 1 and flashed separator oil (FSO) by centrifugation and high-temperature gas chromatography. The dead oils were sub-sampled at 140°F and then centrifuged at 29,000 rpm while the temperature was slowly stepped down from 140°F to 50°F below cloud point for the South Pelto 10 Well 9-2 FSO.

After centrifugation, supernatant and solid samples were taken and sent to Nenniger Engineering for n-paraffin analyses. The Nenniger Engineering results are given in Table 3.1.23. The solid n-paraffin content was obtained from Nenniger data using two different methods. One method was based on a direct analysis of the solids. The other method was to subtract the composition of the supernatant that remained after centrifugation from the composition of the original stock tank oil. Figure 3.1.5 compares the solid n-paraffin distributions obtained by the two methods.

3.1.7.2. D.B. Robinson Associates Precipitation Experiments

D. B. Robinson was subcontracted to make determinations of solid wax contents of the Recombined Oil 1 system. These measurements were completed in the bulk deposition apparatus. This apparatus operates over a similar range of temperatures and pressures as the DBR onset apparatus and facilitates the isolation of a wax sample for qualitative and quantitative analysis. Typically, a live fluid (or dead if necessary) is charged to a blind, high pressure cylinder where it is initially equilibrated at conditions outside the wax formation envelope (i.e. at a temperature greater than the previously measured cloud point). The cylinder is mounted on a rocking mechanism and a Millipore filter is placed in-line so that the discharged solids may be collected. The system temperature is then lowered to the specified measurement value, and after

liquid phase had little effect on stabilizing or altering the characteristics of the precipitating wax fraction.

Appendix I: South Pelto 10 Well 9-2

Index of Figures and Tables

Tables

Table 3.1.1

South Pelto 10 Well 9-2 Sample Summary

Separator Gas

Cylinder Number		Separator Conditions Pressure (psig)	Separator Conditions Temperature (°F)	Laboratory Opening Pressure Pressure (psig)	Laboratory Opening Pressure Temperature (°F)
WL-142		178	66	98	69
WL-167		178	66	175	69
WL-212		178	66	175	69
WL-256		178	66	170	69
WL-284		178	66	169	69
WL-292		178	66	160	69
WL-312	*	178	66	178	69
WL-315		178	66	177	69

Separator Liquid

Cylinder Number		Separator Conditions Pressure (psig)	Separator Conditions Temperature (°F)	Laboratory Bubble Point Conditions Pressure (psig)	Laboratory Bubble Point Conditions Temperature (°F)
WL-170		178	66	164	68
WL-183		178	66	175	69
WL-286	*	178	66	181	69
WL-308		178	66	167	67

* Samples selected for recombination.

Table 3.1.3

South Pelto 10 Well 9-2
Separator Gas Compositions

Component	WL142 Mol %	WL256 Mol %	WL292 Mol %	WL312 Mol %	WL315 Mol %	WL212 Mol %	WL284 Mol %	WL167 Mol %
H2S	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
N2	0.281	0.264	0.270	0.321	0.271	0.229	0.267	0.243
CO2	1.069	1.073	1.082	1.074	1.076	1.084	1.074	1.077
C1	92.410	92.364	92.459	92.486	92.430	92.725	92.372	92.350
C2	3.976	4.005	3.953	3.923	3.981	3.786	4.043	4.024
C3	1.351	1.356	1.333	1.323	1.351	1.283	1.349	1.351
iC4	0.296	0.298	0.295	0.287	0.294	0.288	0.296	0.295
nC4	0.306	0.304	0.305	0.295	0.302	0.297	0.305	0.305
iC5	0.111	0.107	0.107	0.106	0.107	0.105	0.108	0.109
nC5	0.065	0.064	0.063	0.062	0.063	0.049	0.061	0.064
C6	0.070	0.082	0.069	0.067	0.068	0.064	0.067	0.073
C7	0.043	0.042	0.041	0.039	0.040	0.044	0.039	0.055
C8	0.021	0.028	0.020	0.018	0.017	0.027	0.017	0.034
C9	0.000	0.014	0.003	0.000	0.000	0.013	0.002	0.014
C10	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.005
C11	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.001
C12+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

Hydrocarbon Properties

Mol Weight	17.73	17.76	17.72	17.70	17.72	17.69	17.72	17.78
Gas Gravity	0.612	0.613	0.612	0.611	0.612	0.611	0.612	0.614
GPM Value	1.748	1.770	1.734	1.714	1.743	1.686	1.743	1.782
Z Factor at separator conditions	0.969	0.969	0.696	0.969	0.969	0.969	0.969	0.969
BTU Content per dry gas at 14.73 psia and 60°F	1073.3	1075.0	1072.8	1071.3	1073.1	1071.7	1073.1	1076.6

Table 3.1.5

South Pelto 10 Well 9-2
Measured Hydrocarbon Analysis of Recombined Oil 1

Component	Mole Percent	Calculated Mole Percent	Weight Percent	Calculated Weight Percent	Molecular Weight	Specific Gravity
N2	0.00	0.15	0.00	0.04	28	0.8094
CO2	0.59	0.59	0.22	0.22	44	0.8180
C1	46.58	46.14	6.36	6.25	16	0.3000
C2	2.83	2.62	0.73	0.67	30.1	0.3562
C3	1.62	1.49	0.61	0.56	44.1	0.5070
iC4	0.62	0.55	0.31	0.27	58.1	0.5629
nC4	0.89	0.78	0.44	0.39	58.1	0.5840
iC5	0.66	0.61	0.41	0.37	72.2	0.6247
nC5	0.64	0.70	0.40	0.43	72.2	0.6311
C6	1.09	0.75	0.78	0.53	84	0.7094
C7	2.65	3.30	2.17	2.68	96	0.7286
C8	3.86	3.88	3.53	3.51	107	0.7447
C9	3.39	3.59	3.50	3.68	121	0.7606
C10	3.09	3.22	3.53	3.65	134	0.7748
C11	2.56	2.55	3.21	3.18	147	0.7872
C12	2.23	2.53	3.06	3.45	161	0.7990
C13	2.40	2.56	3.58	3.80	175	0.8093
C14	2.40	2.37	3.89	3.82	190	0.8195
C15	2.14	2.25	3.76	3.92	206	0.8298
C16	2.09	1.95	3.95	3.67	222	0.8385
C17	1.69	1.73	3.41	3.47	237	0.8468
C18	1.76	1.67	3.78	3.54	251	0.8531
C19	1.56	1.49	3.49	3.33	263	0.8590
C20	1.42	1.35	3.32	3.14	275	0.8652
C21	1.24	1.23	3.07	3.02	291	0.8713
C22	1.03	1.01	2.69	2.61	305	0.8769
C23	0.99	0.95	2.69	2.55	318	0.8823
C24	0.90	0.83	2.54	2.31	331	0.8873
C25	0.81	0.80	2.40	2.33	345	0.8922
C26	0.70	0.67	2.16	2.03	359	0.8969
C27	0.64	0.65	2.04	2.07	374	0.9013
C28	0.54	0.53	1.80	1.75	388	0.9056
C29	0.55	0.53	1.89	1.79	402	0.9092
C30+	3.85	4.00	20.30	20.96	618	0.9484
	100.00	100.00	100.00	100.00		

Properties of Hydrocarbon Fractions							Calculated Recom	
					mol wt	density	density	mol wt
C7+ Fraction	44.48	45.62	89.75	90.28	236.5	0.8558	0.858	233.6
C11+ Fraction	31.49	31.64	77.02	76.74	286.6	0.8752	0.878	286.3
C15+ Fraction	21.90	21.62	63.28	62.50	338.6	0.8922	0.896	341.2
C20+ Fraction	12.68	12.53	44.89	44.56	415.0	0.9131	0.916	419.7
C30+ Fraction	3.85	4.00	20.30	20.96	618.1	0.9484	0.948	618.0
Overall Reservoir Fluid					117.2	0.7504	0.7543	118.0
Gas Oil Ratio	454.7	scf/bbl of stock tank						

Table 3.1.7

South Pelto 10 Well 9-2

Constant Composition Expansion and Property Measurements of Recombined Oil 1 @ 232°F

Pressure (psia)		Relative Volume (2)	Liquid Volume Percent	Compressibility vol/vol x10-E06)	Oil Density (gm/cc)		Gas Density (gm/cc)		Oil Viscosity (cp)	
6012									0.470	*
5066		0.9765			0.7355	*			0.390	*
4559		0.9822		11.392	0.7313					
4053		0.9882		12.087	0.7268	*			0.367	*
3546		0.9948		13.023	0.7220					
3445		0.9966		14.027	0.7207					
3343		0.9979			0.7198					
3242		0.9992			0.7188					
3221	(1)	1.0000	100.00		0.7182				0.312	
3141		1.0033								
3090		1.0071								
3039		1.0107								
2533		1.0779								
2026		1.1868	82.24							
1874		1.2386	77.79		0.7361	*	0.1197	*	0.666	*
1520		1.3912	68.42							
1013		1.8287	50.44							
506		3.2428	27.60		0.7697	*	0.0219	*	0.953	*

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.1.9

South Pelto10 Well 9-2

Constant Composition Expansion and Property Measurements of Recombined Oil 1 @ 42°F

Pressure (psia)		Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)		Gas Density (gm/cc)		Oil Viscosity (cp)	
5066		0.9851			0.7958	*			9.007	*
4559		0.9880		5.709	0.7935					
4053		0.9909		5.861	0.7911	*			7.252	*
3546		0.9940		6.055	0.7887					
3039		0.9971		6.237	0.7862	*			6.204	*
2735		0.9987			0.7850					
2634		0.9994			0.7844					
2518	(1)	1.0000	100.00		0.7839				5.390	
2432		1.0066								
2330		1.0145								
2229		1.0219								
2026		1.0437								
1520		1.1485	84.43		0.8057	*	0.0992	*	8.2550	*
1013		1.4250	65.03							
506		2.4196	37.61		0.8351	*	0.0288	*	8.2630	*

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.1.11

South Pelto 10 Well 9-2
Measured Hydrocarbon Analysis of Recombined Oil 1
Intermediate Mix of 182 Gas/Oil Ratio

Component	Mole Percent	Weight Percent	Molecular Weight	Specific Gravity
N2	0.00	0.00	28	0.8094
CO2	0.40	0.11	44	0.8180
C1	28.95	2.94	16	0.3000
C2	2.25	0.43	30.1	0.3562
C3	1.69	0.47	44.1	0.5070
iC4	0.69	0.26	58.1	0.5629
nC4	1.01	0.37	58.1	0.5840
iC5	0.73	0.34	72.2	0.6247
nC5	0.85	0.39	72.2	0.6311
C6	1.00	0.53	84	0.7023
C7	3.99	2.43	96	0.7212
C8	5.23	3.55	107	0.7372
C9	4.90	3.76	121	0.7529
C10	4.48	3.81	134	0.7669
C11	3.48	3.25	147	0.7792
C12	3.38	3.45	161	0.7909
C13	3.26	3.62	175	0.8011
C14	3.25	3.92	190	0.8113
C15	3.17	4.14	206	0.8214
C16	2.81	3.96	222	0.8300
C17	2.36	3.54	237	0.8382
C18	2.34	3.73	251	0.8444
C19	2.11	3.52	263	0.8503
C20	1.87	3.27	275	0.8564
C21	1.71	3.15	291	0.8625
C22	1.44	2.79	305	0.8681
C23	1.30	2.63	318	0.8733
C24	1.21	2.55	331	0.8783
C25	1.09	2.39	345	0.8832
C26	0.96	2.18	359	0.8878
C27	0.90	2.14	374	0.8921
C28	0.74	1.82	388	0.8964
C29	0.73	1.87	402	0.9000
C30+	5.71	22.70	626	0.9759
	100.00	100.00		
	Properties of Hydrocarbon Fractions			
C7+ Fraction	62.42	94.16	237.7	0.8549
C11+ Fraction	43.83	80.61	289.9	0.8763
C15+ Fraction	30.46	66.38	343.4	0.8956
C20+ Fraction	17.68	47.49	423.4	0.9216
C30+ Fraction	5.71	22.70	626.1	0.9759
Overall Reservoir Fluid			157.6	0.7986
Gas Oil Ratio	182	scf/bbl of stock tank		

Third Recombination used for cloud point measurements only.
wax and cloud point information only.
Pob = 1260@160°F

Table 3.1.13

South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas

Constant Composition Expansion and Property Measurements of Flow Loop Oil @ 140°F

Pressure (psia)		Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)		Gas Density (gm/cc)		Oil Viscosity (cp)	
2008		0.9905		5.236	0.8175	*			2.689	*
1501		0.9931		6.215	0.8146	*			2.593	*
994		0.9962		8.631	0.8119	*			2.463	*
792		0.9974							2.422	*
589		0.9991			0.8100	*			2.353	*
533	(1)	1.0000	100.00		0.8095				2.337	
516		1.0057								
500		1.0190	96.43							
492		1.0243								
478		1.0406								
386		1.1287	89.05		0.8121	*	0.0162	*	2.460	*
289		1.3161	76.17		0.8141	*	0.0109	*	2.591	*
184		1.7662	57.63		0.8163	*	0.00759	*	2.677	*
97		2.5708	38.24		0.8194	*	0.0024	*	2.816	*

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.1.15

South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas

Constant Composition Expansion and Property Measurements of Flow Loop Oil @ 90°F

Pressure (psia)		Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)		Gas Density (gm/cc)		Oil Viscosity (cp)	
1501		0.9945		4.565	0.8337	*			5.310	*
994		0.9968		5.545	0.8310	*			5.051	*
793		0.9979			0.8303	*			4.935	*
488		0.9996			0.8293	*			4.790	*
423	(1)	1.0000	100.00	6.181	0.829[illegible]				4.721	
361		1.0415	97.27							
333		1.0776	95.02							
309		1.1105	93.53							
285		1.1545	89.42							
234		1.2912	80.03		0.8345	*	0.0111	*	5.244	*
97		2.6074	42.03		0.8387	*	0.0045	*	5.470	*

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.1.17

South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas

Constant Composition Expansion and Property Measurements of Flow Loop Oil @ 40°F

Pressure (psia)		Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)		Gas Density (gm/cc)	Oil Viscosity (cp)
1501		0.9947			0.8531	*		
994		0.9964		3.312	0.8491	*		
792		0.9972		4.011	0.8477	*		
488		0.9986		4.777	0.8454	*		
386		0.9993						
309	(1)	1.0000	100.00		0.8440			
275		1.1216						
184		1.4479	70.89					
97		2.4422	44.89					

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

NOTE: Gas and oil densities below bubble point pressure as well as viscosity data could not be obtained due to excessive wax buildup.

Table 3.1.19

South Pelto 9-2 Stock Tank Oil & City of Tulsa Synthesized Gas
Summary of Wax Data (°F)
for Flow Loop Oil

Pressure	FTIR		FP	
psig	WAT	WDT	WAT	WDT
1,000	107	134	110	137
1,500	103	132		
3,000	113	145	115	140
5,000	124	138		

FTIR = FOURIER TRANSFORM INFRARED SPECTROSCOPY
FP= FILTER PLUGGING
WAT = WAX APPEARANCE TEMPERATURE
WDT = WAX DISSOLUTION TEMPERATURE

Table 3.1.21

Stock Tank Oil Density From Recombined Oil 1 and Recombined Oil 2

	South Pelto 10 Well 9-2	Main Pass 299 Well B-4
Temperature °F	Density gm/cc	Density gm/cc
60	0.8496	0.8263
100	0.8346	0.8103
122	0.8269	0.8020
140	0.8205	0.7944

TABLE 3.1.23

Flashed Separator Oil Used For the Solids Analysis by Nenniger

	n-Paraffin Analyses Before Cooling			n-Paraffin Analyses After Cooling			n-Paraffin Analyses Solids			
CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %	*Recombined* Wax Frxn *0.06*
17	1.0249	15.5573	6.5876	1.143	18.840	6.069				1.0747584
18	0.8352	12.6781	5.5627	0.880	14.494	4.926				0.826824
19	0.6156	9.3453	4.7276	0.632	10.406	4.046				0.5936194
20	0.5764	8.7504	4.1119	0.576	9.494	3.414				0.541628
21	0.3691	5.6034	3.5355	0.389	6.402	2.838				0.3652088
22	0.3720	5.6471	3.1664	0.390	6.422	2.450				0.3683368
23	0.3576	5.4285	2.7944	0.383	6.311	2.060				0.3600106
24	0.3321	5.0413	2.4367	0.341	5.624	1.677				0.3208596
25	0.2923	4.4367	2.1046	0.261	4.293	1.336	0.2413	1.81457	13.2979	0.2593762
26	0.2390	3.6286	1.8124	0.241	3.964	1.075	0.26511	1.99362	13.0566	0.2420518
27	0.1869	2.8370	1.5733	0.181	2.979	0.835	0.2713	2.04017	12.79149	0.1862206
28	0.1736	2.6356	1.3864	0.169	2.776	0.654	0.32959	2.47851	12.52019	0.1781654
29	0.1713	2.6005	1.2128	0.156	2.565	0.485	0.42772	3.21645	12.1906	0.1720024
30	0.1200	1.8210	1.0415	0.096	1.580	0.330	0.46483	3.49551	11.76288	0.1179982
31	0.0971	1.4744	0.9216	0.070	1.152	0.234	0.54541	4.10147	11.29805	0.0984588
32	0.0944	1.4327	0.8244	0.060	0.996	0.164	0.57216	4.30263	10.75264	0.0911714
33	0.0733	1.1132	0.7300	0.042	0.699	0.103	0.57049	4.29008	10.18048	0.0741042
34	0.0573	0.8694	0.6567	0.026	0.428	0.061	0.54695	4.11305	9.60999	0.0572476
35	0.0477	0.7247	0.5994	0.016	0.268	0.035	0.53068	3.9907	9.06304	0.047144
36	0.0399	0.6058	0.5517	0.008	0.137	0.019	0.49721	3.73901	6.53236	0.037644
37	0.0311	0.4720	0.5118	0.004	0.088	0.010	0.52145	3.9213	8.03515	0.0351786
38	0.0345	0.5243	0.4807	0.004	0.064	0.006	0.51726	3.88979	7.5137	0.034664
39	0.0432	0.6552	0.4462	0.002	0.038	0.002	0.4806	3.6141	6.99644	0.0310262
40	0.0382	0.5799	0.4030				0.4851	3.64794	6.51584	0.029106
41	0.0350	0.5310	0.3648				0.42719	3.21246	6.03074	0.0256314
42	0.0424	0.6438	0.3298				0.52647	3.95905	5.60355	0.0315882
43	0.0302	0.4584	0.2874				0.39922	3.00213	5.07708	0.0239532
44	0.0287	0.4349	0.2572				0.43042	3.23675	4.67786	0.0258252
45	0.0221	0.3347	0.2286				0.37885	2.84895	4.24744	0.022731
46	0.0223	0.3385	0.2065				0.43573	3.27668	3.86859	0.0261438
47	0.0203	0.3088	0.1842				0.35654	2.68117	3.43286	0.0213924
48	0.0189	0.2869	0.1639				0.36315	2.73088	3.07632	0.021789
49	0.0190	0.2884	0.1450				0.31088	2.33781	2.71317	0.0186528
50	0.0238	0.3608	0.1260				0.37686	2.83398	2.40229	0.0226116
51	0.0156	0.2371	0.1022				0.27328	2.05506	2.02543	0.0163968
52	0.0124	0.1881	0.0866				0.22357	1.68124	1.75215	0.0134142
53	0.0096	0.1450	0.0742				0.19538	1.46925	1.52858	0.0117228
54	0.0082	0.1251	0.0646				0.16234	1.22079	1.3332	0.0097404
55	0.0071	0.1082	0.0564				0.13737	1.03302	1.17086	0.0082422
56	0.0058	0.0882	0.0493				0.10887	0.8187	1.03349	0.0065322
57	0.0051	0.0776	0.0435				0.09652	0.72583	0.92462	0.0057912
58	0.0046	0.0694	0.0383				0.0836	0.62867	0.8281	0.005016
59	0.0042	0.0643	0.0338				0.07999	0.60152	0.7445	0.0047994
60	0.0035	0.0532	0.0295				0.06639	0.49925	0.66451	0.0039834
61	0.0036	0.0550	0.0260				0.06555	0.49293	0.59812	0.003933
62	0.0030	0.0454	0.0224				0.05432	0.40849	0.53257	0.0032592
63	0.0029	0.0440	0.0194				0.05178	0.38938	0.47825	0.0031088
64	0.0023	0.0342	0.0165				0.04122	0.30997	0.42647	0.0024732
65	0.0022	0.0336	0.0143				0.04343	0.32659	0.38525	0.0026058
66	0.0018	0.0273	0.0121				0.03622	0.27237	0.34182	0.0021732
67	0.0019	0.0280	0.0103				0.04116	0.30952	0.3056	0.0024696
68	0.0014	0.0209	0.0084				0.03236	0.24335	0.26444	0.0019416
69	0.0014	0.0208	0.0070				0.03198	0.24049	0.23208	0.0019188
70	0.0010	0.0152	0.0057				0.02706	0.20349	0.2001	0.0016236
71	0.0011	0.0161	0.0047				0.02799	0.21048	0.17304	0.0016794
72	0.0007	0.0105	0.0036				0.0203	0.15266	0.14505	0.001218
73	0.0008	0.0113	0.0029				0.02248	0.16905	0.12475	0.0013488
74	0.0005	0.0068	0.0022				0.01509	0.11348	0.10227	0.0009054
75	0.0005	0.0074	0.0017				0.01802	0.13551	0.08718	0.0010812
76	0.0003	0.0043	0.0013				0.01122	0.08437	0.06916	0.0006732
77	0.0003	0.0044	0.0010				0.01331	0.10009	0.05794	0.0007986
78	0.0002	0.0027	0.0007				0.00932	0.07009	0.04463	0.0005592
79	0.0002	0.0025	0.0005				0.00914	0.06873	0.03531	0.0005484
80	0.0001	0.0015	0.0003				0.00676	0.05084	0.02617	0.0004056
81							0.00663	0.04986	0.01941	0.0003978
82							0.00357	0.02685	0.01278	0.0002142
83							0.00277	0.02083	0.00921	0.0001662
84							0.00213	0.01602	0.00644	0.0001278
85							0.00235	0.01767	0.00431	0.000141
86							0.00121	0.0091	0.00196	0.0000726
87							0.00075	0.00564	0.00075	0.000045

Table 3.1.25

RECOMBINED OIL - BULK DEPOSITION:
LIQUID COMPOSITION @ 4000 psia, 58°F

COMPONENT	MW	GAS MOLE %	LIQUID WT %	OVERALL WT %	MOLE %	GROUP MOLE %
CO2	44.01	1.158	0.000	0.263	0.657	0.657
H2S	34.08	0.000	0.000	0.000	0.000	0.000
N2	28.01	0.258	0.000	0.037	0.146	0.146
C1	16.04	85.958	0.000	7.126	48.752	48.752
C2	30.07	5.279	0.000	0.820	2.994	2.994
C3	44.1	2.959	0.057	0.725	1.804	1.804
I-C4	58.12	1.014	0.072	0.369	0.697	0.697
N-C4	58.12	1.303	0.157	0.532	1.005	1.005
I-C5	72.15	0.622	0.282	0.484	0.736	0.736
N-C5	72.15	0.422	0.266	0.396	0.602	0.602
C6	85	0.513	0.936	1.066	1.357	
MCYC-C5	84.16	0.044	0.223	0.219	0.286	
BENZENE	78.11	0.177	0.000	0.071	0.100	
CYCL-C6	82.15	0.065	0.256	0.257	0.343	2.087
C7	99	0.040	1.518	1.379	1.511	
MCYCL-C6	98.19	0.068	0.715	0.675	0.754	
TOLUENE	92.14	0.005	0.732	0.657	0.783	
C8	113	0.015	2.024	1.821	1.749	
C2-BENZENE	106.17	0.006	0.104	0.096	0.099	
M&P-XYLENE	106.17	0.041	0.889	0.818	0.846	
O-XYLENE	106.17	0.037	0.486	0.456	0.471	
C9	128.3	0.013	2.169	1.950	1.668	7.882
C10	134	0.002	3.907	3.499	2.866	
C11	147	0.002	3.675	3.291	2.457	
C12	161	0.001	3.689	3.303	2.252	
C13	175	0.000	4.572	4.093	2.567	
C14	190	0.001	4.337	3.884	2.244	12.386
C15	206	0.000	4.542	4.066	2.166	
C16	222	0.000	4.043	3.620	1.790	
C17	237	0.000	4.022	3.601	1.668	
C18	251	0.000	4.015	3.594	1.572	
C19	263	0.000	3.808	3.409	1.423	8.618
C20	275	0.000	3.446	3.085	1.231	
C21	291	0.000	3.170	2.838	1.070	
C22	305	0.000	2.913	2.608	0.938	
C23	318	0.000	2.759	2.470	0.852	
C24	331	0.000	2.572	2.302	0.763	
C25	345	0.000	2.520	2.256	0.718	
C26	359	0.000	2.080	1.862	0.569	
C27	374	0.000	2.170	1.943	0.570	
C28	388	0.000	2.264	2.027	0.573	
C29	402	0.000	2.373	2.125	0.580	7.867
C30+	580	0.000	22.235	19.905	3.767	3.767
MW=		20.3	227		109.76	
DENSITY=	0.781	g/cm3 at	58	°F &	4000	psia
WT. GAS/ WT. SAMPLE=			0.092			
GOR @ STD		100.4	(M3/M3)	563.4	(SCF/BBL)	

Table 3.1.27

RECOMBINED OIL
BULK DEPOSITION SUMMARY DATA
(@ 800 psia, 50°F)

Initial Charge of Recombined Oil
(@ 4000 psia, 160°F)

Mass:	85.07 g
Density:	0.767 g/cm3
Volume:	110.91 cm3

Reduce Temperature to 24°F and Equilibrate at 4000 psia

Liquid Phase:

Mass:	76.11 g
Density:	0.843 g/cm3
Volume:	90.28 cm3

Vapor Phase:

Mass:	4.58 g
Density:	0.0538 g/cm3
Volume:	85.21 cm3

Solid Phase:

Mass:	4.38 g
Density:	0.85 g/cm3
Volume:	5.15 cm3
Thermal Conductivity	0.23 W/m.K
	1.6 Btu/[(h.ft2)(°F/in)]

Weight Fraction Solids Precipitated @ 800 psia, 50°F: 5.1%

Table 3.1.29

RECOMBINED OIL - BULK DEPOSITION:
FILTERED SOLID COMPOSITION @ 800 psia, 50°F

CarbonNumber	Mol. Weight	n-Paraffin(wt%)	non n- Paraffin (wt%)	CarbonNumber	Mol. Weight	n-Paraffin(wt%)	n- Paraffin (wt%)
C10	134	0.665	0.968	C44	545	0.567	0
C11	147	1.083	3.104	C45	551	0.459	0
C12	161	1.104	2.891	C46	556	0.391	0
C13	175	1.566	4.093	C47	561	0.355	0
C14	190	2.551	3.818	C48	566	0.324	0
C15	206	2.671	3.083	C49	571	0.271	0
C16	222	2.443	2.936	C50	575	0.237	0
C17	237	3.042	2.811	C51	580	0.208	0
C18	251	2.556	2.513	C52	584	0.162	0
C19	263	2.336	2.41	C53	588	0.139	0
C20	275	2.383	2.155	C54	592	0.102	0
C21	291	1.694	2.13	C55	596	0.088	0
C22	305	1.676	1.336	C56	600	0.04	0
C23	318	1.67	1.961	C57	604	0.045	0.015
C24	331	1.63	1.615	C58	608	0.035	0
C25	345	1.438	1.508	C59	612	0.02	0
C26	359	1.292	1.526	C60	615	0.019	0
C27	374	1.091	1.602	C61	619	0.009	0
C28	388	1.091	1.486	C62	622	0.003	0
C29	402	1.055	1.293	C63	626	0.003	0
C30	422	0.895	1.251	C64	629	0.002	0
C31	435	0.783	1.112	C65	632	0.001	0
C32	448	0.667	1.071	C66	635	0.001	0
C33	462	0.698	0.912	C67	638	0.002	0
C34	473	0.7	0.804				
C35	485	0.715	0.696	Totals:		42.986	53.516
C36	493	0.528	0.711				
C37	501	0.467	0.665				
C38	509	0.446	0.318				
C39	516	0.361	0.303				
C40	522	0.401	0.247				
C41	528	0.369	0.187				
C42	534	0.301	0				
C43	540	0.618	0				

Figure 3.1.2

South Pelto 10 Well 9-2
Cloud Point Data for Recombined Oil 1

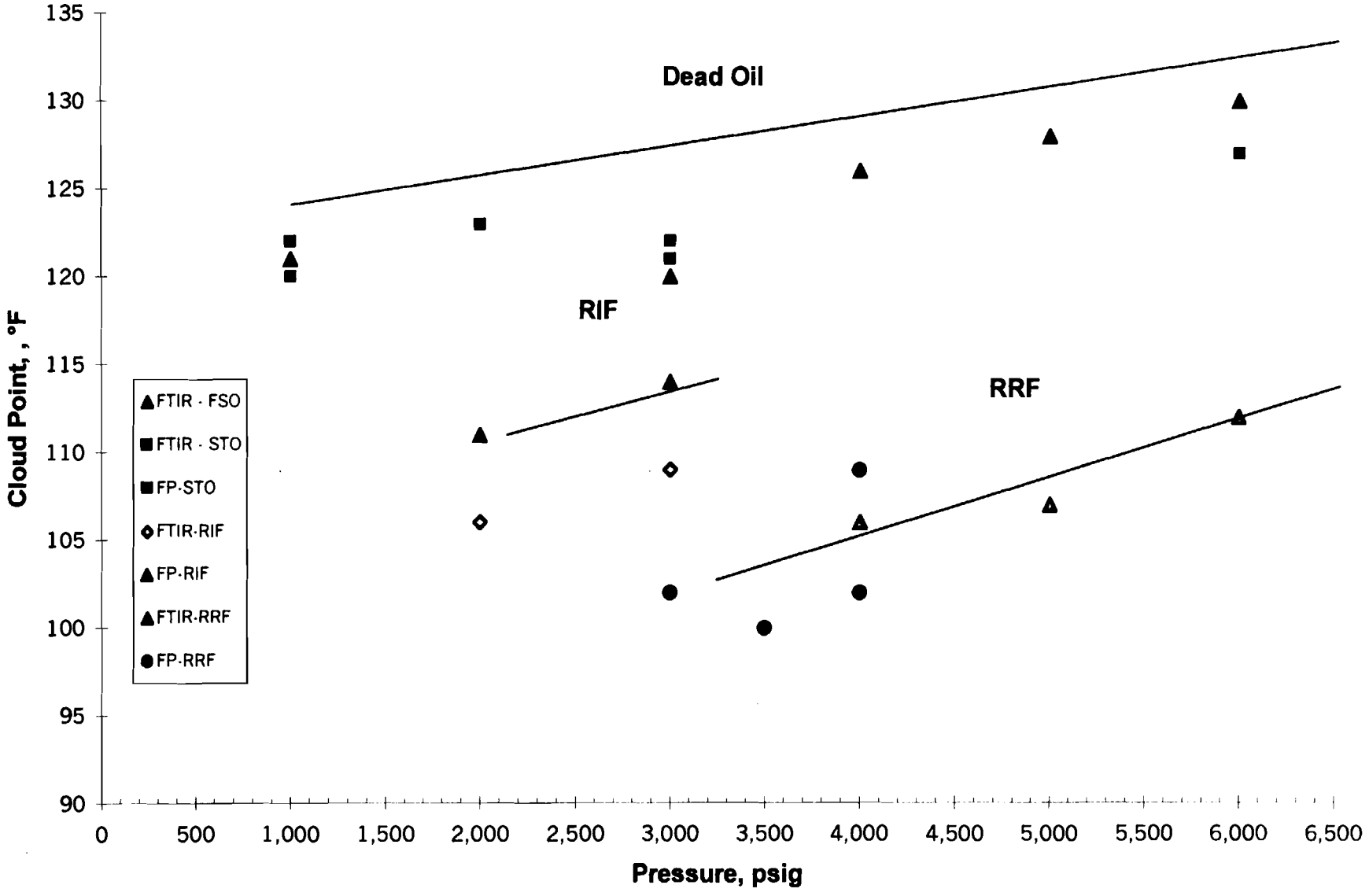


Figure 3.1.4

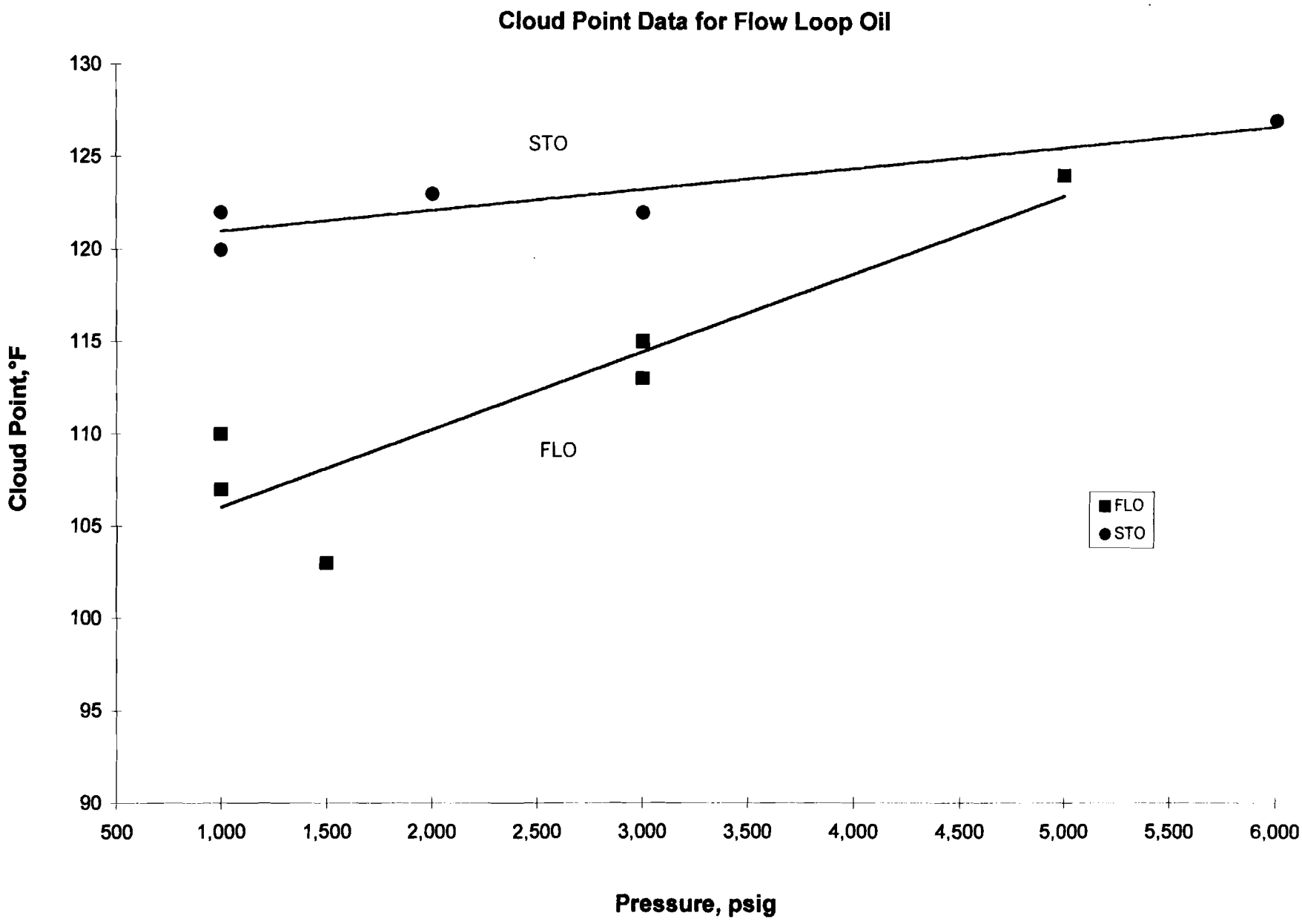

Cloud Point Data for Flow Loop Oil
Cloud Point, °F
130
125
120
115
110
105
100
95
90
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
Pressure, psig
STO
FLO
FLO
STO

Figure 3.1.6

Recombined Oil: Reproducibility Test:
Cloud Point Determinations at 4000 psia

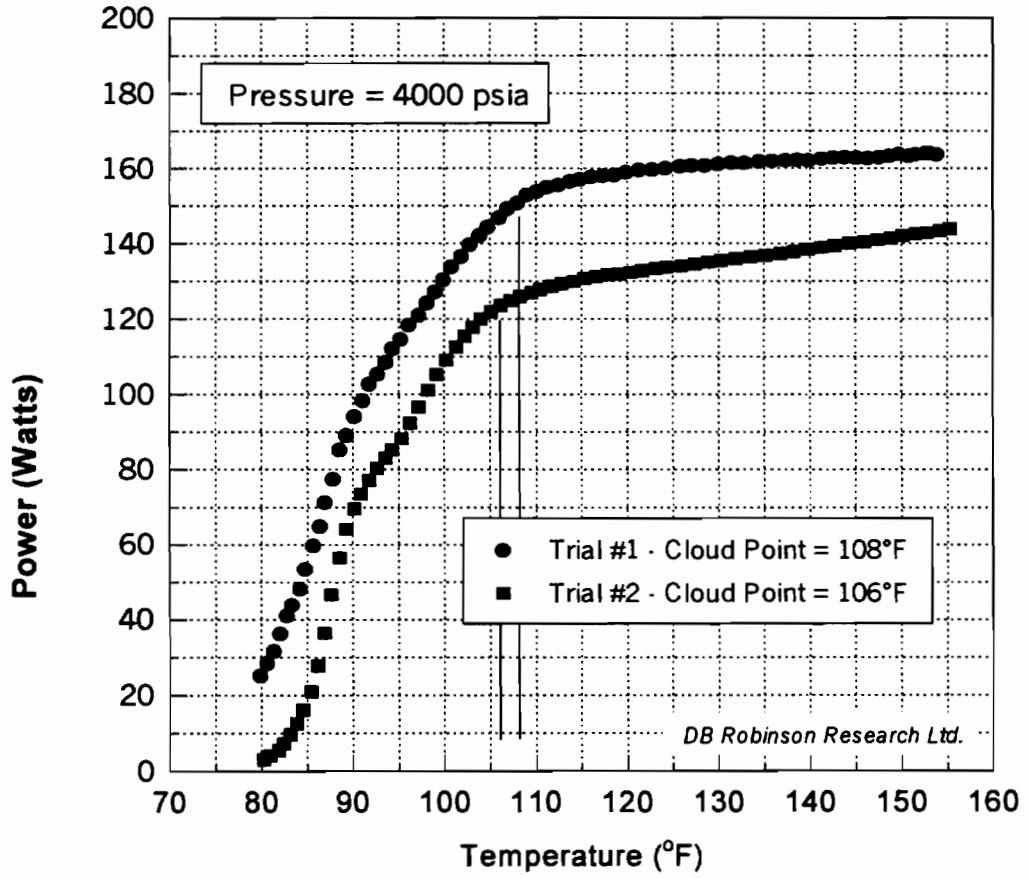
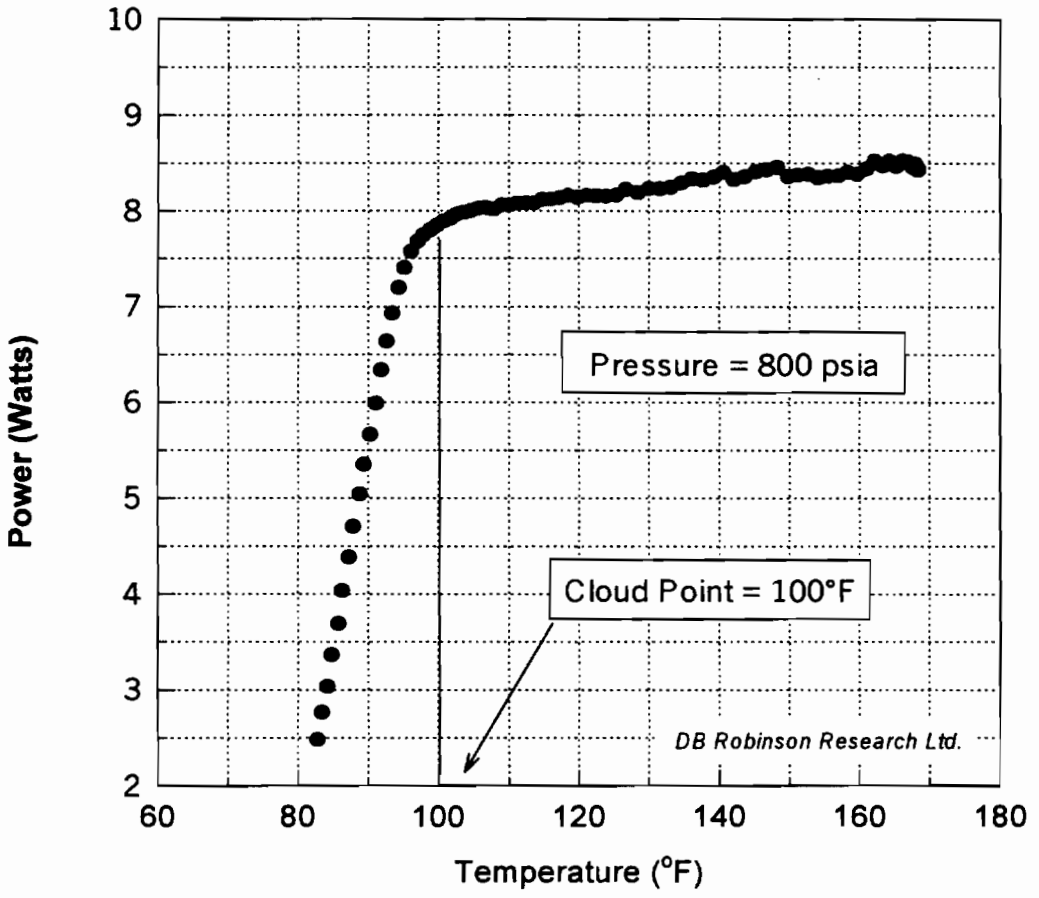


Figure 3.1.8

Recombined Oil: Two Phase
Cloud Point Determination at 800 psia
(vapor phase expelled)



Appendix 3.2: Garden Banks 426 Well A-14 Reservoir Fluid Characterization and Property Evaluation Study

3.2. Condensate – Garden Banks 426, Well A-14

Weatherly Laboratories collected separator samples on August 8, 1996 from Shell Oil Company's Garden Banks 426 Well A-14. Duplicate samples were collected, resulting in a total of sixteen separator gas samples and six separator liquid samples. These samples, plus (2) one gallon cans of stock-tank oil, arrived at Marathon Oil Company's Petroleum Technology Center (PTC) in Littleton Colorado on August 16, 1996. A summary of the samples collected is given in Table 3.2.1 and a summary of the API Gravity of the all stock tank oils produced in these tests in Table 3.2.2.

3.2.1. Separator Samples

As a quality check, the opening pressure of the separator gases and the bubble point pressure of the separator liquids were determined at ambient temperature. These results are presented in Table 3.2.1. Prior to taking any sample outage, each separator liquid cylinder was conditioned by being heated to 120°F and pressurized to 3,000 psig. Each separator gas cylinder was also conditioned by being heated to 120°F.

Compositions were determined for selected separator gas and liquid samples. The compositional results are shown in Tables 3.2.3 and 3.2.4. The separator liquid compositions are reported through C_{30+}. The mass percent values were measured. The properties of the individual C_{6+} fractions were not measured but rather estimated. The molecular weights of the C_6-C_{29} fractions were values reported by Katz and Firoozabadi[1] for general petroleum fractions. The specific gravity values for C_6-C_{30+} fractions were calculated using a constant Watson K factor of 12.01. The C_{30+} molecular weight and overall Watson K factor were calculated to match the molecular weight measured by Freezing Point Depression, and the 60°F density value measured by using a Paar-Mettler densitometer, for the stabilized liquid created from the separator liquid. Table 3.2.2 compares the API gravities of the different samples tested in this work.

All separator gas and liquid samples from Garden Banks 426 Well A-14 have been transferred to Marathon Oil Company storage containers for use in the JIP Project. All 22 empty cylinders belonging to Weatherly Laboratories were sent back to their facility on September 10, 1996.

3.2.2. Recombination to Reservoir Fluid

Conditions for mixing Recombined Condensate were made to that of current wellhead conditions of 6400 psig and 100°F. Through various discussions with representatives of Marathon Oil Company's Petroleum Technology Center, Shell Oil Company, and The University of Tulsa, a decision was made as to the conditions to use in the PVT portion of the Recombined Condensate Study. In conforming to the original contract, temperatures used will be reservoir temperature of 176°F, then 138°F, and 100°F. Pressures to be used will be the saturation pressure, 4000 psig, and 2000 psig.

---

[1] Katz, D. L. and Firoozabadi, A., "Predicting Phase Behavior of Condensate Crude Oil Systems using methane Interaction Coefficients", J. Pet. Tech., November 1978, pp. 1649 – 1655.

bubble point pressure were linearly interpolated from the measured single-phase oil values. All oil densities and viscosities denoted by an asterisk were measured. The viscosity, density, and CCE data are presented in Table 3.2.7. A graph of the liquid volume percent is presented in Figure 3.2.3.

As stated in the scope of work, the fluid in the PVT cell was expanded down to 2000 psig. At this pressure, some equilibrated gas was pumped off to the densitometer. Then all remaining gas was pumped out of the PVT cell until the 2000 psig equilibrated oil was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscometer, while maintaining constant temperature and pressure.

After the 2000 psig measurements, a subsequent sample of conditioned Recombined Condensate was charged to the PVT cell. The bubble point of this fluid was verified. Property data at the intermediate pressure of 4000 psig was then obtained. This data may also be found in Table 3.2.7.

Constant Composition Expansion @ 138°F

A portion of Recombined Condensate (Garden Banks 426 Well A14) conditioned at 8000 psig and 176°F, was charged into a high-pressure visual PVT cell, contained within an airbath and thermally equilibrated at a temperature of 138°F. The fluid was then subjected to a Constant Composition Expansion (CCE). During this expansion a bubble point pressure of 6521 psig was observed. After continuing the CCE below the bubble point pressure, it was observed that the fluid represents behavior of a near critical volatile oil system.

As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscometer, both at 138°F. Single-phase density and viscosity measurements were taken at various pressures. The oil density and viscosity at the bubble point pressure were linearly interpolated from the measured single-phase oil values. All oil densities and viscosities denoted by an asterisk were measured. CCE, density, and viscosity data are presented in Table 3.2.8.

As stated in the scope of work, the fluid in the PVT cell was expanded down to 2000 psig. At this pressure, some equilibrated gas was pumped off to the densitometer. Then all remaining gas was pumped out of the PVT cell until the 2000 psig equilibrated oil was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscometer, while maintaining constant temperature and pressure.

After the 2000 psig measurements, a subsequent sample of conditioned Recombined Condensate was charged to the PVT cell. The bubble point of this fluid was verified, then property data at the intermediate pressure of 4000 psig was obtained. This data may also be found in Table 3.2.8.

Constant Composition Expansion @ 100°F

A portion of Recombined Condensate (Garden Banks 426 Well A14) conditioned at 8000 psig and 100°F, was charged into a high-pressure visual PVT cell, contained within an airbath and thermally equilibrated at a temperature of 100°F. The fluid was then subjected to a Constant Composition Expansion (CCE). During this expansion a bubble point pressure of 6575 psig was observed. After continuing the CCE below the bubble point pressure, it was observed that the fluid still represented behavior of a near critical volatile oil system.

As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscometer, both at 100°F. Single-phase density and viscosity measurements were taken at various pressures. The oil density and viscosity at the

The fluid in the PVT cell was expanded down to 200 psig. Some equilibrated gas was pumped off to the densitometer and then collected into a small high-pressure cylinder for compositional analysis at this pressure. This data may be found in Table 3.2.12. All remaining gas was pumped out of the PVT cell until the oil equilibrated at 200 psig was all that remained in the PVT cell. A portion of the oil phase was then pumped to the densitometer and the viscometer, while maintaining constant temperature and pressure. All remaining oil at 200 psig was pumped out of the PVT cell and collected into a small cylinder for compositional analysis. This data may be found in Table 3.2.13.

After the 200 psig measurements, subsequent samples of conditioned Flow Loop Condensate were charged to the PVT cell. The bubble point of this fluid was verified each time, then property data at the intermediate pressures of 400 psig, 300 psig, and 100 psig were obtained. This data may also be found in Table 3.2.11.

Constant Composition Expansion @ 90°F

A portion of Flow Loop Condensate, still conditioned at 1,500 psig and 140°F was charged into a high-pressure visual PVT cell at a temperature of 90°F. This fluid was then subjected to a CCE. During this expansion a bubble point pressure of 432 psig was observed.

The same procedure used in the other CCE experiments was used to measure the data given in Table 3.2.14 for the Flow Loop Condensate at 90°F.

The fluid in the PVT cell was then expanded down to 204 psig. The same procedure as was used at 140° was used to obtain samples for the analysis given in Tables 3.2.15 and 3.2.16.

After the 204 psig measurements, another sample of conditioned Flow Loop Condensate was charged to the PVT cell. The bubble point of this fluid was verified, then property data at the intermediate pressures of 303 and 105 psig were obtained. This data may also be found in Table 3.2.14.

Constant Composition Expansion @ 40°F

A portion of Flow Loop Condensate, still conditioned at 1,500 psig and 140°F, was charged into a high-pressure visual PVT cell at 40°F. The fluid was then subjected to a CCE. During this expansion a bubble point pressure of 364 psig was observed. The fluid in the PVT cell was expanded down to a final pressure of 100 psig. The CCE and density data are presented in Table 3.2.17. The gas density data were not reported because of problems in the density determination at these low temperatures.

After the initial CCE measurements, another sample of conditioned Flow Loop Condensate was charged to the PVT cell. The bubble point of this fluid was verified, then the fluid in the PVT cell was then expanded down to 200 psig. The gas and oil compositions were determined as before and are given in Tables 3.2.18 and 3.2.19.

No viscosity data was obtained due to wax plugging in the capillary coil viscometer. Despite several attempts, this problem could not be corrected. Wax was apparently plating out inside the viscometer below the bubble point pressure at 40°F. This made viscosity determination impossible and the experiments were terminated at that point.

Comparisons of viscosity, density, liquid volume percent, and relative volume data for Flow Loop Condensate are shown graphically in Figures 3.2.5, 3.2.6, 3.2.7, and 3.2.8, respectively.

quantify this material. Nenniger found that the bottoms contained 16.4 weight % C_{22+} n-paraffins. This calculated to a solid n-paraffin in the condensate of 0.89%. When the weight % solid n-paraffin in the condensate was calculated from the difference of C_{22+} n-paraffins in the original condensate and the top layer from the centrifuge test, the value was 0.46%. The difference between 0.89% and 0.46% was larger than what Marathon found for the Main Pass or South Pelto oils. We do not know the cause of this difference, nor which value is correct. The "oil difference" value of 0.46% should be less affected by the presence of clay or water in the sample. The condensate only contained 0.5% water, so this should not have caused the problem. A plot of the n-paraffin distribution data from the two different techniques is shown in Figure 3.2.10. It is interesting to note that the two curves are superimposable when the "oil difference" values are multiplied by two and compared to the "solid analysis" values. This Figure again illustrates the futility of trying to gauge the precipitate composition from the difference in two oil compositions.

3.2.5.2. Recombined Condensate Bulk Deposition Measurement @ 8000 psia, 25°F

Table 3.2.24 contains the summary data from the bulk deposition trial completed at 8000 psia and 25°F for the recombined condensate. One can determine that the precipitated wax content at 25°F was 0.83 wt% and that the density of the produced solid was 0.842 g/cm^3 from the data in the table. Note that both the density and the measured thermal conductivity (0.22 W/m.K), are quite close to those measured for the solids precipitated from the recombined oil. As a result, it may be hypothesized (at least with the small sample set available at this stage) that solid wax properties do not appear to be heavily dependent on composition. Of course, this assumes that the solids precipitated in this project are different in composition and that may not be the case.

Table 3.2.25 and 3.2.26 contain the analysis of the produced liquid and filtered solid from this test. As expected, the liquid composition is quite close to that of the original single phase condensate (especially in the light components) but slightly lower in the heavier, wax forming molecules (e.g., C_{30+} for the single phase fluid is 0.496 mole % while for the liquid it is 0.451 mole %). A second observation is the fluid density that has increased from 0.515 g/cm^3 to 0.570 g/cm^3 despite the loss of some heavy components. The reason for this difference is found in the measurement temperatures for the fluids (140°F for the single-phase condensate and 25°F for the liquid from the test).

To conclude this trial, the composition of the produced solid phase is provided to C_{80+} including a resolution into n-paraffin and non n-paraffin fractions at each carbon number (see Table 3.2.26). The molecular weight distributions of this solid are somewhat similar to those obtained from the recombined oil although the concentration of lighter components is slightly higher. This observation is most likely a function of the lower operating temperature for this trial (25°F) which causes an increased portion of the lighter molecules to solidify. In any event, it is difficult to prove or disprove the earlier hypothesis with this data, as the solid compositions do not appear markedly different.

3.2.5.3. Recombined Condensate Bulk Deposition Measurement @ 4000 psia, 25°F

The second recombined condensate bulk deposition test was completed at 4000 psia and 24°F and the overall volumetric data have been summarized in Table 3.2.27 (note, this trial represented a Vapor-Liquid-Solid equilibrium). In this experiment, the precipitated wax content was found to be 1.6 wt% and in addition, the properties of the solid (i.e., density and thermal conductivity) were quite close to those measured for the three other waxes.

Table 3.2.28 and 3.2.29 contain the compositional analyses of the phases produced in this trial. From Table 3.2.28, the liquid composition has changed significantly from the liquid in the 8000 psia trial but that is mainly a function of the vapor phase. For example, the 4000 psia liquid now has a methane content of 53.571 mole % (down from 71.394 mole %) and a density of

Appendix II: Garden Banks

Index of Tables and Figures

Tables

Table 3.2.1

Garden Banks 426 Well A-14
Sample Summary

Separator Gas

Cylinder Number	Separator Conditions Pressure (psig)	Separator Conditions Temperature (°F)	Laboratory Opening Pressure Pressure (psig)	Laboratory Opening Pressure Temperature (°F)
WLE-371	1902	109	1695	71
WLE-375	1902	109	1695	71
WLE-289	1902	109	1680	70
WLE-296	1902	109	1690	72
WLE-386	1902	109	1660	71
WLE-303	1902	109	940	71
WLE-380	1902	109	1640	72
WLE-377	1902	109	1680	72
WLE-212 *	1902	109	1720	71
WLE-370	1902	109	1650	70
WLE-239	1902	109	1720	72
WLE-208	1902	109	1710	72
WLE-288	1902	109	1690	72
WLE-382	1902	109	1650	72
WLE-387	1902	109	1680	71
WLE-368	1902	109	1580	72

Separator Liquid

Cylinder Number	Separator Conditions Pressure (psig)	Separator Conditions Temperature (°F)	Laboratory Bubble Point Conditions Pressure (psig)	Laboratory Bubble Point Conditions Temperature (°F)
WLE-379 *	1902	109	1721	74
WLE-376	1902	109	1702	74
WLE-292	1902	109	1711	74
WLE-290	1902	109	1680	74
WLE-068	1902	109	1696	74
WLE-301	1902	109	1716	74

* Samples selected for compositional analyses.

Table 3.2.3

Garden Banks 426 Well A-14
Separator Gas Compositional Analysis

Cylinder No. WLE 212

Component	Mol %	Weight %
H2S	0.00	0.00
C02	0.23	0.54
N2	0.10	0.15
C1	89.26	75.63
C2	5.50	8.74
C3	2.46	5.72
iC4	0.47	1.45
nC4	0.74	2.28
iC5	0.26	1.00
nC5	0.27	1.04
C6	0.33	1.46
C7	0.20	1.00
C8	0.12	0.70
C9	0.04	0.29
C10	0.00	0.00
C11	0.00	0.00
C12	0.00	0.00
	100.00	100.00

Sample collected at	1919 psia and 109°F	
Gas molecular weight	18.9	g/mol
Gas Gravity	0.654	
BTU Content	1183	per dry gas at 14.73 psia and 60°F.
GPM Value	3.082	
Z Factor	0.790	at 1919 psia and 109°F
Gas Density, gm/cc	0.1207	at 1919 psia and 109°F

Table 3.2.5

Garden Banks 426 Well A14
Hydrocarbon Analysis of Recombined Condensate

Component	Calculated Mole Percent	Calculated Weight Percent	Determined Mole Percent	Determined Weight Percent	Molecular Weight	Specific Gravity
N2	0.11	0.07	0.03	0.02	28	0.8094
CO2	0.17	0.17	0.10	0.10	44	0.8180
C1	71.39	25.90	71.51	26.30	16	0.3000
C2	5.94	4.04	6.20	4.29	30.1	0.3562
C3	3.35	3.34	3.44	3.49	44.1	0.5070
iC4	0.85	1.11	0.85	1.14	58.1	0.5629
nC4	1.42	1.87	1.58	2.11	58.1	0.5840
iC5	0.72	1.17	0.76	1.26	72.2	0.6247
nC5	0.83	1.35	0.90	1.50	72.2	0.6311
C6	1.56	2.96	1.40	2.71	84	0.7063
C7	1.83	3.98	2.02	4.46	96	0.7254
C8	1.99	4.82	1.96	4.82	107	0.7414
C9	1.48	4.04	1.27	3.53	121	0.7573
C10	1.23	3.72	1.14	3.50	134	0.7714
C11	0.93	3.08	0.84	2.85	147	0.7837
C12	0.75	2.72	0.72	2.65	161	0.7955
C13	0.66	2.60	0.64	2.59	175	0.8058
C14	0.61	2.61	0.56	2.44	190	0.8159
C15	0.53	2.47	0.48	2.28	206	0.8261
C16	0.44	2.23	0.43	2.22	222	0.8348
C17	0.34	1.84	0.36	1.94	237	0.8431
C18	0.33	1.89	0.31	1.78	251	0.8493
C19	0.29	1.75	0.28	1.72	263	0.8552
C20	0.26	1.64	0.25	1.56	275	0.8613
C21	0.23	1.52	0.22	1.47	291	0.8674
C22	0.18	1.27	0.18	1.28	305	0.8731
C23	0.17	1.25	0.17	1.26	318	0.8784
C24	0.15	1.12	0.15	1.11	331	0.8833
C25	0.14	1.12	0.13	1.07	345	0.8883
C26	0.12	0.95	0.11	0.91	359	0.8929
C27	0.11	0.90	0.11	0.93	374	0.8973
C28	0.09	0.82	0.09	0.84	388	0.9016
C29	0.09	0.85	0.09	0.82	402	0.9051
C30+	0.70	8.83	0.70	9.08	563	0.9414
	100.00	100.00	100.00	100.00		
Properties of Hydrocarbon Fractions						
C7+ Fraction	13.67	58.02	13.22	57.09	188	0.8246
C11+ Fraction	7.14	41.46	6.83	40.78	260	0.8606
C15+ Fraction	4.20	30.45	4.07	30.25	324	0.8842
C20+ Fraction	2.26	20.26	2.20	20.31	401	0.9074
C30+ Fraction	0.70	8.83	0.70	9.08	563	0.9414
Reservoir Fluid					43.5	0.5064
Gas Oil Ratio			4006			

Table 3.2.7

Garden Banks 426 Well A14

Constant Composition Expansion and Property Measurements of Recombined Condensate @ 176°F

Pressure (psig)		Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)		Gas Density (gm/cc)		Oil Viscosity (cp)	
8001		0.9496		31.446	0.5168	*			0.207	*
7500		0.9648		32.962	0.5111	*			0.198	*
6999		0.9810			0.5042	*			0.188	*
6700		0.9917			0.4995	*			0.183	*
6600		0.9950		35.055						
6501		0.9980								
6457	(1)	1.0000	100.00		0.4965				0.178	
6446		1.0010	53.35							
6420		1.0035	53.07							
6401		1.0053	52.85							
6351		1.0088	52.82							
6000		1.0332	52.67							
5001		1.0868	50.86		0.5790	*				
4002		1.2060	45.72		0.6190	*	0.2516	*	0.343	*
3002		1.4329	37.36							
2001		1.9929	25.61		0.6808	*	0.1103	*	0.470	*

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.2.9

Garden Banks 426 Well A14

Constant Composition Expansion and Property Measurements of Recombined Condensate @ 100°F

Pressure (psig)	Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E05)	Oil Density (gm/cc)	Gas Density (gm/cc)	Oil Viscosity (cp)
8000	0.9689		1.638	0.5515 *		0.147 *
7500	0.9769		2.215	0.5466 *		0.145 *
7000	0.9878		2.765	0.5419 *		0.144 *
6700	0.9961		3.120	0.5391 *		0.143 *
6600	0.9995					
6575 (1)	1.0000	100.00		0.5379		0.142
6560	1.0005					
6550	1.0016	68.75				
6538	1.0019	66.09				
6530	1.0022	64.99				
6500	1.0027	62.51				
6400	1.0065	60.04				
6000	1.0189	58.54				
4000	1.2303	48.35		0.6188 *	0.2984 *	0.369 *
2000	1.7505	32.10		0.6782 *	0.1316 *	0.512 *

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.2.11

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas

Constant Composition Expansion and Property Measurements of Flow Loop Condensate @ 140°F

Pressure (psig)	Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)	Gas Density (gm/cc)	Oil Viscosity (cp)
2000	0.9885		7.576	0.7750 *		1.218 *
1500	0.9923		7.728	0.7720 *		1.147 *
1000	0.9962		8.407	0.7693 *		1.086 *
800	0.9979		9.253	0.7680		1.060 *
600	0.9996			0.7665 *		*
576	(1) 1.0000	100.00		0.7663		1.027
550	1.0148					
525	1.0386					
500	1.0632	92.53				
400	1.2004	81.48		0.7698 *	0.0187 *	1.090 *
300	1.4562	66.58		0.7728 *	0.0140 *	1.154 *
200	1.9893	46.66		0.7758 *	0.0105 *	1.241 *
100	2.9394	17.81		0.7800 *	0.0063 *	1.352 *

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.2.13

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas
Compositional Analysis of Flow Loop Condensate
Equilibrium Oil at 200 psig and 140°F

Component	Mole Percent	Weight Percent	Molecular Weight	Specific Gravity
N2	0.00	0.00	28.0	0.8094
CO2	0.03	0.01	44.0	0.8180
C1	2.55	0.22	16.0	0.3000
C2	0.64	0.11	30.1	0.3562
C3	0.91	0.22	44.1	0.5070
iC4	0.54	0.17	58.1	0.5629
nC4	1.45	0.46	58.1	0.5840
iC5	1.36	0.54	72.2	0.6247
nC5	2.61	1.03	72.2	0.6311
C6	4.10	1.89	84	0.6957
C7	8.99	4.73	96	0.7145
C8	11.18	6.55	107	0.7303
C9	9.11	6.04	121	0.7459
C10	7.99	5.86	134	0.7598
C11	6.22	5.00	147	0.7720
C12	5.33	4.70	161	0.7836
C13	4.68	4.48	175	0.7937
C14	4.14	4.31	190	0.8037
C15	3.53	3.99	206	0.8138
C16	2.92	3.56	222	0.8223
C17	2.55	3.32	237	0.8305
C18	2.23	3.06	251	0.8366
C19	2.00	2.89	263	0.8424
C20	1.69	2.55	275	0.8485
C21	1.56	2.49	291	0.8545
C22	1.27	2.11	305	0.8600
C23	1.16	2.03	318	0.8652
C24	1.03	1.87	331	0.8701
C25	0.97	1.84	345	0.8750
C26	0.79	1.56	359	0.8796
C27	0.76	1.56	374	0.8838
C28	0.62	1.33	388	0.8881
C29	0.65	1.43	402	0.8916
C30+	4.41	18.10	750	0.9579
	100.00	100.00		
	Properties of Hydrocarbon Fractions			
C7+ Fraction	85.81	95.36	203	0.8242
C11+ Fraction	48.54	72.18	272	0.8562
C15+ Fraction	28.18	53.69	348	0.8827
C20+ Fraction	14.93	36.88	451	0.9102
C30+ Fraction	4.41	18.10	750	0.9579
Overall Reservoir Fluid			182.6	0.8098

Table 3.2.15

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas
Compositional Analysis of Flow Loop Condensate

Equilibrium Gas at 200 psig and 90°F

Component	Mol %	Weight %
H2S	0.00	0.00
C02	0.40	0.99
N2	2.89	4.56
C1	92.75	83.85
C2	1.67	2.84
C3	0.82	2.05
iC4	0.24	0.80
nC4	0.45	1.48
iC5	0.20	0.81
nC5	0.21	0.86
C6	0.22	1.05
C7	0.09	0.49
C8	0.02	0.12
C9	0.01	0.06
C10	0.00	0.02
C11	0.00	0.01
C12	0.00	0.01
	100.00	100.00

Sample collected at	200 psig and 90°F	
Gas molecular weight	17.7	g/mol
Gas Gravity	0.613	
BTU Content	1067	per dry gas at 15.025 psia and 60°F.
GPM Value	1.211	
Z Factor	0.979	at 200 psig and 90°F
Gas Density, gm/cc	0.0101	at 200 psig and 90°F

Table 3.2.17

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas

Constant Composition Expansion and Property Measurements of Flow Loop Condensate @ 40°F

Pressure (psia)		Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)		Gas Density (gm/cc)	Oil Viscosity (cp)
2004		0.9919			0.8118	*		
1501		0.9942		4.592	0.8085	*		
1007		0.9966		4.886	0.8050	*		
810		0.9975		5.150	0.8035	*		
599		0.9987		5.532	0.8022	*		
404		0.9996						
364	(1)	1.0000	100.00		0.8003			
357		1.0100						
300		1.0816	90.81					
200		1.3444	74.22		0.8048	*		
100		2.0471	48.57		0.8073	*		

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

NOTE: Gas densities could not be measured. Viscosity data could not be obtained due to excessive wax buildup.

Table 3.2.19

Garden Banks 426 Stock Tank Oil & City of Tulsa Synthesized Gas Compositional Analysis of Flow Loop Condensate Equilibrium Oil at 200 psig and 40°F

Component	Mole Percent	Weight Percent	Molecular Weight	Specific Gravity
N2	0.00	0.00	28	0.8094
CO2	0.05	0.01	44	0.8180
C1	1.56	0.14	16	0.3000
C2	0.83	0.14	30.1	0.3562
C3	1.07	0.26	44.1	0.5070
iC4	0.61	0.19	58.1	0.5629
nC4	1.58	0.50	58.1	0.5840
iC5	1.42	0.56	72.2	0.6247
nC5	2.69	1.06	72.2	0.6311
C6	4.19	1.92	84	0.7036
C7	9.06	4.74	96	0.7226
C8	11.23	6.55	107	0.7386
C9	9.14	6.03	121	0.7544
C10	8.01	5.85	134	0.7684
C11	6.23	5.00	147	0.7807
C12	5.34	4.69	161	0.7924
C13	4.69	4.48	175	0.8027
C14	4.15	4.30	190	0.8128
C15	3.54	3.98	206	0.8230
C16	2.93	3.55	222	0.8316
C17	2.56	3.31	237	0.8399
C18	2.23	3.06	251	0.8460
C19	2.01	2.88	263	0.8519
C20	1.70	2.55	275	0.8580
C21	1.57	2.49	291	0.8641
C22	1.27	2.11	305	0.8697
C23	1.17	2.02	318	0.8750
C24	1.04	1.87	331	0.8800
C25	0.98	1.84	345	0.8849
C26	0.80	1.56	359	0.8895
C27	0.76	1.55	374	0.8938
C28	0.63	1.33	388	0.8981
C29	0.65	1.43	402	0.9017
C30+	4.33	18.07	765	0.9677
	100.00	100.00		
	Properties of Hydrocarbon Fractions			
C7+ Fraction	86.01	95.23	203	0.8333
C11+ Fraction	48.58	72.05	272	0.8656
C15+ Fraction	28.16	53.59	349	0.8924
C20+ Fraction	14.88	36.81	454	0.9201
C30+ Fraction	4.33	18.07	765	0.9677
Overall Reservoir Fluid			183.4	0.8188

Table 3.2.21

Garden Banks 426 Well A-14

Summary of Wax Point Data (°F) for Condensate Fluids

	FTIR					FP					DSC	CPM
Pressure	LSO		STO	FLC	RC	LSO		STO	FLC	FLC*	FSO	FSO
psig	WAT	WDT	WAT	WAT	WAT	WAT	WDT	WAT	WAT	WAT	WAT	WAT
1,000			94					96			99	104
1,500								97		91		
2,000									89			
2,500						76	113					
3,000	84	104	104	90				98	91	89		
3,500						88	111					
4,000	83	103										
5,000	86	106	112	95								
7,000					70							

FTIR = FOURIER TRANSFORM INFRARED SPECTROSCOPY (ENERGY SCATTERING)
FP= FILTER PLUGGING
DSC = DIFFERENTIAL SCANNING CALORIMETRY
CPM = CROSSED POLARIZATION MICROSCOPY
LSO = LIVE SEPARATOR OIL
FSO = FLASHED SEPARATOR OIL
STO = DEAD STOCK TANK OIL
WAT = WAX APPEARANCE TEMPERATURE
WDT = WAX DISSOLUTION TEMPERATURE
FLC = FLOW LOOP CONDENSATE
FLC* = FLOW LOOP CONDENSATE (REPEAT ANALYSIS)
RC = RECOMBINED CONDENSATE

Table 3.2.23

Garden Banks 426 A-14 (Recombined Condensate)
Before Cooling n-Paraffin Analyses

CARBON NUMBER	WEIGHT PERCENT	NORMALIZED WEIGHT %	CUMULATIVE WEIGHT %	CARBON NUMBER	WEIGHT PERCENT	NORMALIZED WEIGHT %	CUMULATIVE WEIGHT %
17	0.73487	20.71372	3.54774	51	0.00309	0.0871	0.02275
18	0.57759	16.28049	2.81287	52	0.00242	0.06821	0.01966
19	0.35202	9.92236	2.23528	53	0.00208	0.05863	0.01724
20	0.2923	8.23904	1.88326	54	0.00168	0.04735	0.01516
21	0.24763	6.97993	1.59096	55	0.00154	0.04341	0.01348
22	0.19689	5.54972	1.34333	56	0.00136	0.0384	0.01194
23	0.19945	5.62188	1.14644	57	0.00121	0.03415	0.01058
24	0.14943	4.21197	0.94699	58	0.00111	0.03126	0.00937
25	0.10676	3.00924	0.79756	59	0.00111	0.03131	0.00826
26	0.101	2.84688	0.6908	60	0.00094	0.0265	0.00715
27	0.08862	2.49793	0.5898	61	0.00093	0.02624	0.00621
28	0.06539	1.84314	0.50118	62	0.00079	0.02224	0.00528
29	0.06936	1.95505	0.43579	63	0.00076	0.02148	0.00449
30	0.04841	1.36453	0.36643	64	0.00064	0.01792	0.00373
31	0.04445	1.25291	0.31802	65	0.00058	0.01645	0.00309
32	0.04148	1.16919	0.27357	66	0.00043	0.01223	0.00251
33	0.03846	1.08407	0.23209	67	0.00039	0.01093	0.00208
34	0.02417	0.68128	0.19363	68	0.00033	0.00934	0.00169
35	0.01966	0.55415	0.16946	69	0.00029	0.00828	0.00136
36	0.01619	0.45635	0.1498	70	0.00019	0.00549	0.00106
37	0.01613	0.45466	0.13361	71	0.0002	0.00561	0.00087
38	0.01408	0.39687	0.11748	72	0.00015	0.00418	0.00067
39	0.01104	0.31118	0.1034	73	0.00014	0.00395	0.00052
40	0.00884	0.24917	0.09236	74	0.00008	0.00215	0.00038
41	0.01003	0.28271	0.08352	75	0.00008	0.00233	0.00031
42	0.00962	0.27116	0.07349	76	0.00005	0.00137	0.00022
43	0.00588	0.16574	0.06387	77	0.00005	0.00134	0.00017
44	0.00695	0.1959	0.05799	78	0.00004	0.00112	0.00013
45	0.006	0.16912	0.05104	79	0.00003	0.00098	0.00009
46	0.00607	0.17109	0.04504	80	0.00002	0.00057	0.00005
47	0.00448	0.12628	0.03897	81	0.00002	0.0006	0.00003
48	0.00447	0.126	0.03449	82	0.00001	0.0003	0.00001
49	0.00374	0.10542	0.03002				

Garden Banks 426 A-14 (Recombined Condens
After Cooling n-Paraffin Analyses

CARBON NUMBER	WEIGHT PERCENT	ORMALIZE WEIGHT %	UMULATIVE WEIGHT %
17	0.76481	23.4697	3.25872
18	0.59856	18.368	2.49391
19	0.37201	11.4158	1.89535
20	0.31765	9.7477	1.52334
21	0.26954	8.27135	1.20569
22	0.18952	5.81579	0.93615
23	0.1911	5.86427	0.74663
24	0.14719	4.51681	0.55553
25	0.10363	3.18009	0.40834
26	0.08701	2.67007	0.30471
27	0.06682	2.0505	0.2177
28	0.05175	1.58805	0.15088
29	0.03647	1.11915	0.09913
30	0.02198	0.6745	0.06266
31	0.016	0.49114	0.04068
32	0.01068	0.32777	0.02467
33	0.00657	0.20167	0.01399
34	0.00323	0.09903	0.00742
35	0.00136	0.04173	0.00419
36	0.00105	0.03236	0.00283
37	0.00069	0.02114	0.00178
38	0.00057	0.01734	0.00109
39	0.00034	0.01045	0.00052
40	0.00018	0.00562	0.00018

Table 3.2.25
Recombined Condensate - Bulk Deposition:
Liquid Composition @ 8000 psia, 25°F

		GAS	LIQUID	OVERALL		GROUP
COMPONENT	MW	MOLE %	WT %	WT %	MOLE %	MOLE %
CO2	44.01	0.127	0	0.112	0.11	0.11
H2S	34.08	0	0	0	0	0
N2	28.01	0.234	0	0.132	0.202	0.202
C1	16.04	82.706	0	26.61	71.394	71.394
C2	30.07	6.746	0	4.068	5.824	5.824
C3	44.1	3.927	0.092	3.525	3.441	3.441
I-C4	58.12	1.007	0.082	1.22	0.903	0.903
N-C4	58.12	1.82	0.276	2.277	1.686	1.686
I-C5	72.15	0.801	0.382	1.375	0.82	0.82
N-C5	72.15	0.88	0.632	1.63	0.973	0.973
C6	85	0.874	2.796	3.09	1.543	
MCYC-C5	84.16	0.081	0.352	0.336	0.172	
BENZENE	78.11	0.006	0.087	0.058	0.032	
CYCL-C6	82.15	0.065	0.51	0.395	0.207	1.954
C7	99	0.349	4.15	3.045	1.308	
MCYCL-C6	98.19	0.005	1.202	0.688	0.302	
TOLUENE	92.14	0.034	0.1	0.119	0.056	
C8	113	0.167	6.252	3.914	1.475	
C2-BENZENE	106.17	0.006	0.071	0.054	0.022	
M&P-XYLENE	106.17	0.006	0.479	0.282	0.114	
O-XYLENE	106.17	0.013	0.056	0.06	0.024	
C9	128.3	0.047	6.497	3.79	1.272	4.572
C10	134	0.034	6.676	3.861	1.24	
C11	147	0.018	5.638	3.237	0.948	
C12	161	0.02	4.998	2.886	0.772	
C13	175	0.017	4.907	2.832	0.697	
C14	190	0.006	4.494	2.561	0.58	4.236
C15	206	0.004	4.307	2.448	0.511	3.884
C16	222	0	3.868	2.185	0.424	
C17	237	0	3.543	2.001	0.363	
C18	251	0	3.407	1.924	0.33	
C19	263	0	3.202	1.809	0.296	1.924
C20	275	0	2.872	1.622	0.254	
C21	291	0	2.538	1.433	0.212	
C22	305	0	2.43	1.372	0.194	
C23	318	0	2.196	1.24	0.168	
C24	331	0	1.993	1.126	0.146	
C25	345	0	1.885	1.064	0.133	
C26	359	0	1.653	0.933	0.112	
C27	374	0	1.618	0.914	0.105	
C28	388	0	1.582	0.894	0.099	
C29	402	0	1.408	0.795	0.085	1.508
C30+	580	0	10.77	6.083	0.451	0.451
	MW=	21.7	177.7		43	
	DENSITY=	0.57	g/cm3 at 25°F & 8000 psia			
VT. GAS/ WT. SAMPLE=			0.435			
	GOR @ STD	704.8	(M3/M3)	3957.3	(SCF/BBL)	

Table 3.2.27

Recombined Condensate
Bulk Deposition Summary Data
(@ 4000 psia, 24°F)

Initial Charge of Recombined Condensate
(@ 8500 psia, 140°F)

Mass:	46.34	g
Density:	0.515	g/cm3
Volume:	89.98	cm3

Reduce Temperature to 24°F and Equilibrate at 4000 psia

Liquid Phase:

Mass:	33.88	g
Density:	0.71	g/cm3
Volume:	47.72	cm3

Vapor Phase:

Mass:	11.74	g
Density:	0.328	g/cm3
Volume:	35.8	cm3

Solid Phase: **Solid Precipitated @ 4000 psia, 24°F: 1.6%**

Mass:	0.72	g
Density:	0.838	g/cm3
Volume:	0.86	cm3
Thermal Conductivity:	0.23	W/m.K
	1.5	Btu/[(h.ft2)(°F/in)]

Table 3.2.29
Recombined Condensate - Bulk Deposition: Filtered Solid Composition @ 4000 psia, 24°F

CarbonNumber	Mol. Weight	n-Paraffin(wt%)	non n- Paraffin (wt%)	CarbonNumber	Mol. Weight	n-Paraffin(wt%)	non n- Paraffin (wt%)
C10	134	1.542	5.169	C44	545	0.301	0.253
C11	147	2.157	4.49	C45	551	0.246	0.227
C12	161	1.909	4.488	C46	556	0.234	0.198
C13	175	1.784	4.616	C47	561	0.181	0.168
C14	190	1.594	4.289	C48	566	0.161	0.134
C15	206	1.476	3.639	C49	571	0.128	0.112
C16	222	1.624	2.696	C50	575	0.199	0.097
C17	237	1.198	2.599	C51	580	0.158	0
C18	251	1.077	2.559	C52	584	0.126	0
C19	263	1.458	2.101	C53	588	0.097	0
C20	275	0.864	1.633	C54	592	0.086	0
C21	291	0.838	1.575	C55	596	0.06	0
C22	305	0.905	1.232	C56	600	0.066	0
C23	318	0.696	0.929	C57	604	0.033	0
C24	331	0.762	1.019	C58	608	0.053	0
C25	345	1.021	0.886	C59	612	0.021	0
C26	359	1.403	0.698	C60	615	0.048	0
C27	374	1.733	0.692	C61	619	0.014	0
C28	388	2.057	0.644	C62	622	0.036	0
C29	402	2.282	0.598	C63	626	0.012	0
C30	422	2.158	0.562	C64	629	0.028	0
C31	435	2.191	0.548	C65	632	0.004	0
C32	448	1.775	0.463	C66	636	0.017	0.006
C33	462	1.49	0.59	C67	639	0.004	0
C34	473	1.259	0.595	C68	642	0.013	0
C35	485	1.101	0.566	C69	646	0.007	0
C36	493	0.956	0.56				
C37	501	0.841	0.509				
C38	509	0.736	0.48				
C39	516	0.602	0.453				
C40	522	0.542	0.394				
C41	528	0.449	0.358				
C42	534	0.419	0.316				
C43	540	0.338	0.288	Totals:		45.568	54.432

Figure 3.2.2
Garden Banks 426 Well A-14
Density Data for Recombined Condensate

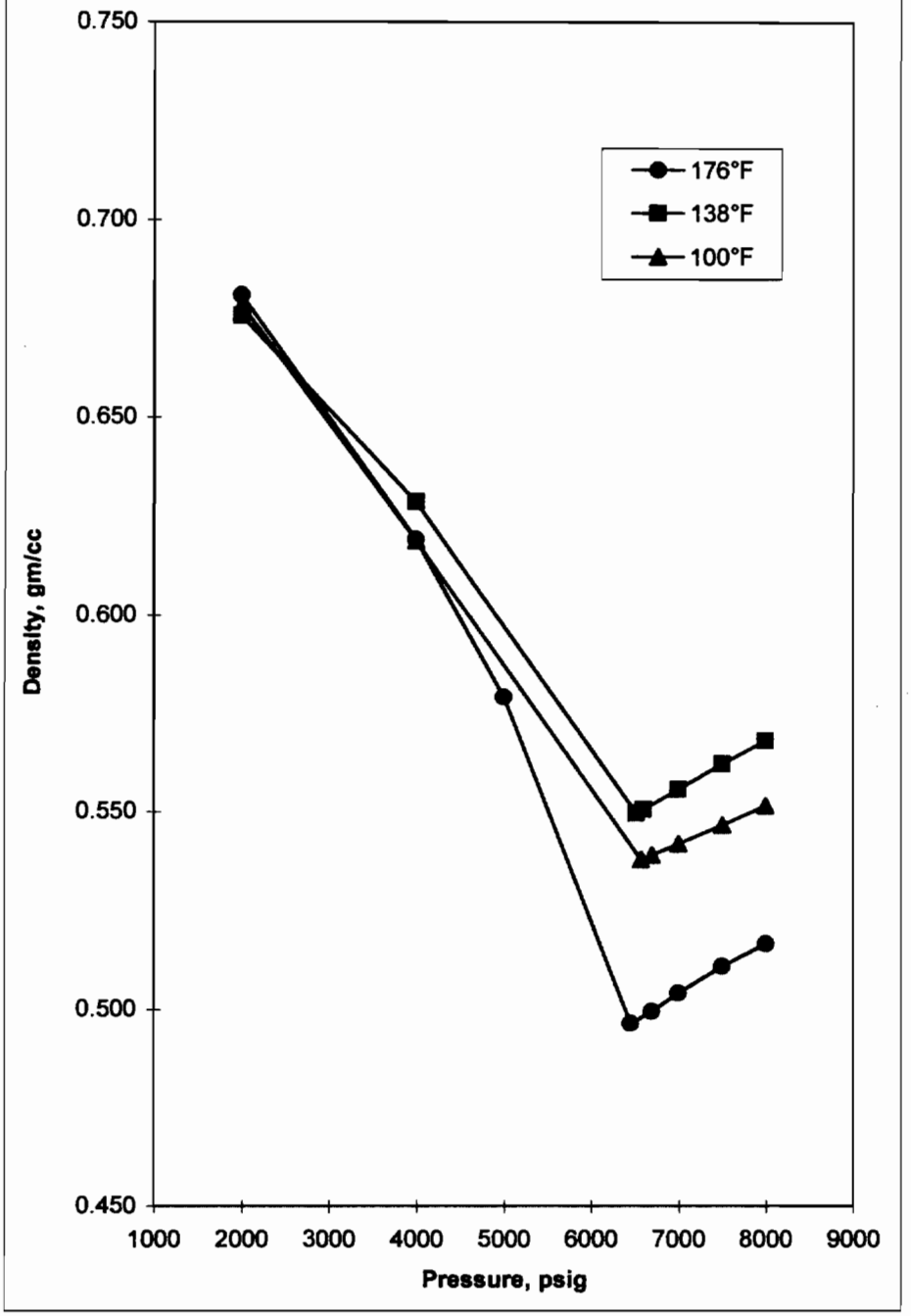


Figure 3.2.4
Garden Banks 426 Well A-14
Relative Volume Data for Recombined Condensate

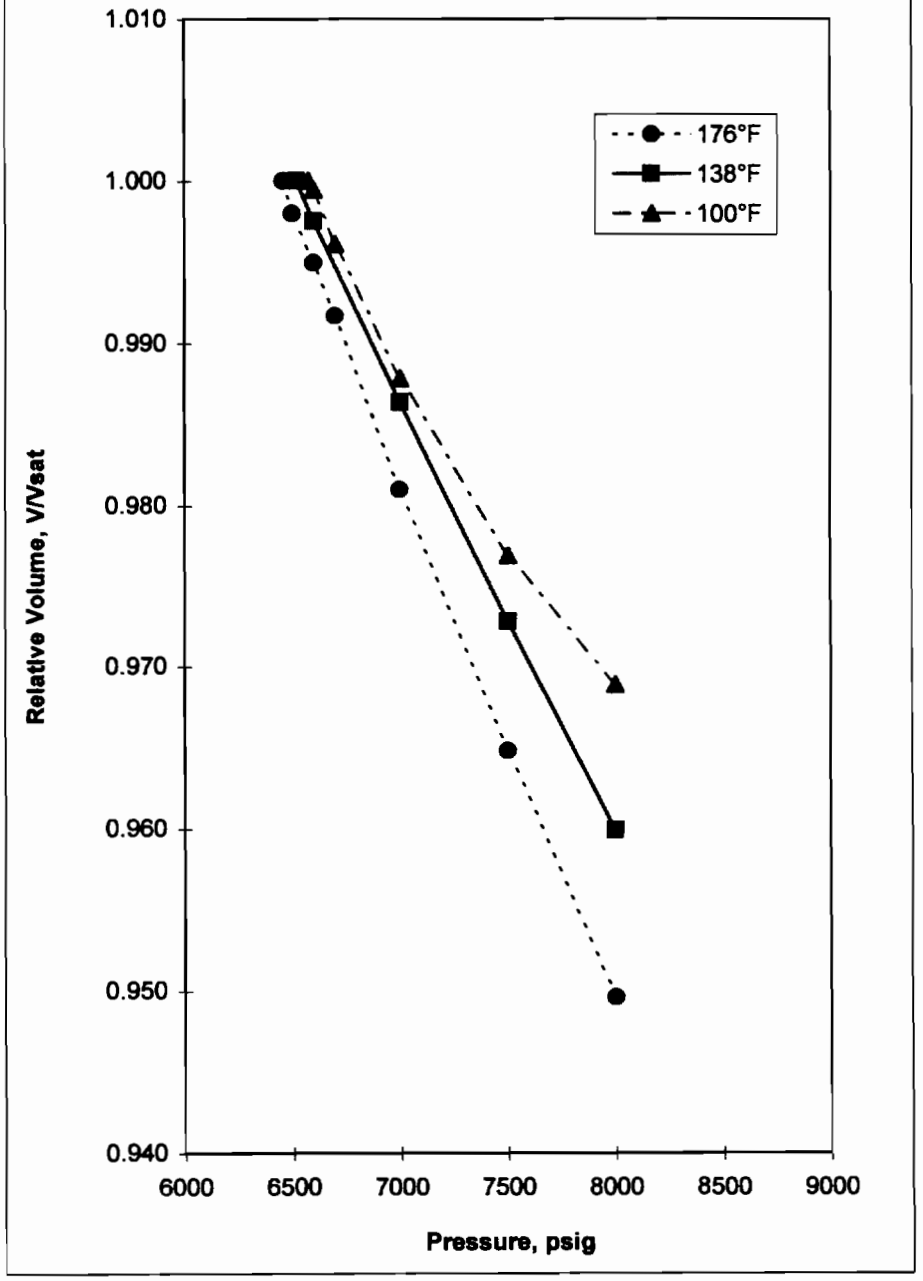


Figure 3.2.8
Garden Banks 426 Stock Tank Oil and City of Tulsa Gas
Relative Volume Data for Flow Loop Condensate

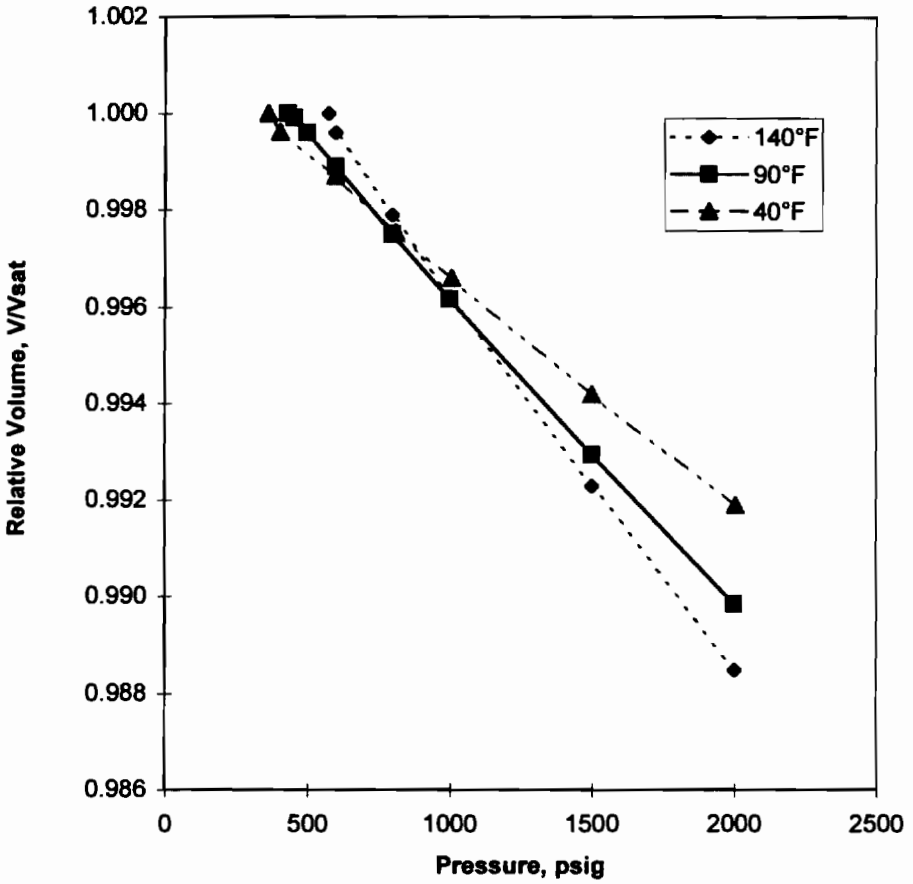
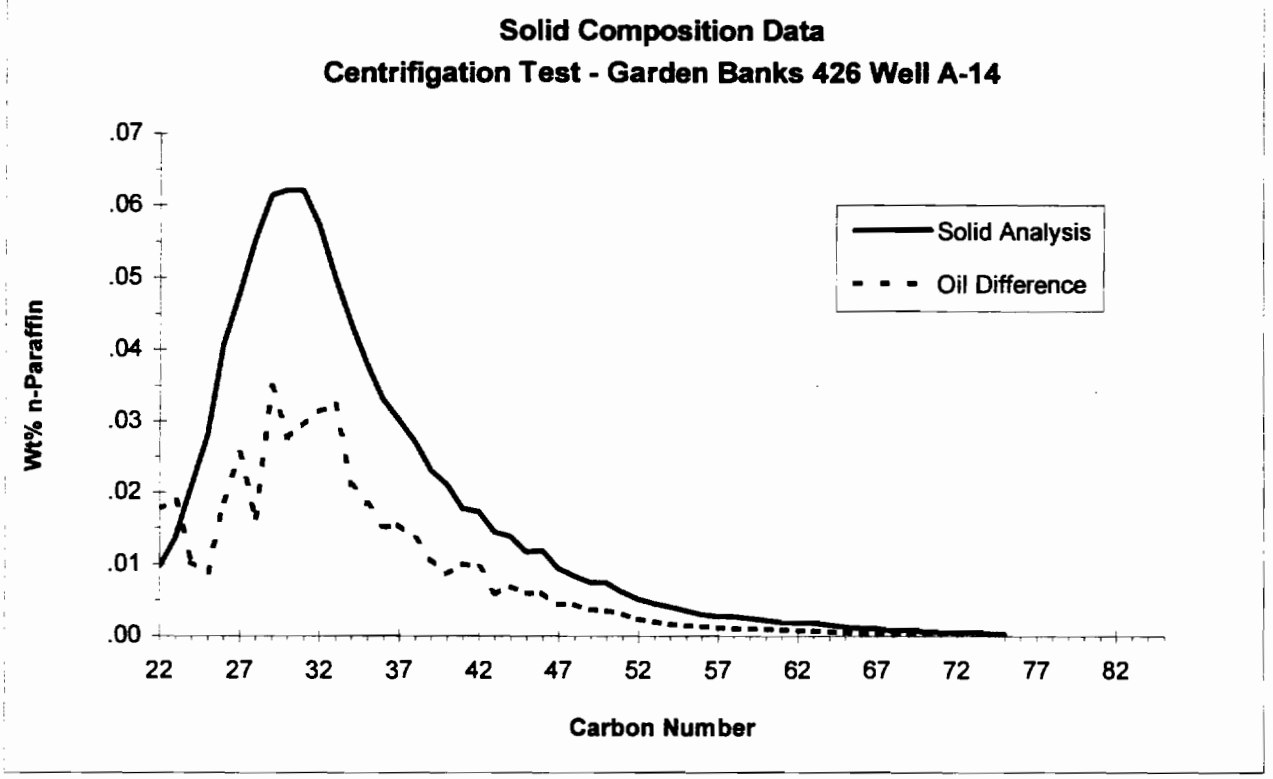


Figure 3.2.10


Solid Composition Data
Centrifigation Test - Garden Banks 426 Well A-14
Wt% n-Paraffin
.07
.06
.05
.04
.03
.02
.01
.00
22
27
32
37
42
47
52
57
62
67
72
77
82
Carbon Number
Solid Analysis
Oil Difference

Appendix 3.3: Main Pass 299 Well B-4 Fluid Characterization and Property Evaluation Study

3.3. Oil 2 – Main Pass 299

On March 11, 1996, Weatherly Laboratories sampled Chevron's Main Pass 299 Well No. B-4 to be used for The University of Tulsa's JIP Recombined Oil No. 2. Duplicate samples were collected resulting in a total of five separator gas samples and two separator oil samples. These samples, plus a five gallon can of stock tank oil, arrived at Marathon Oil Company's Petroleum Technology Center (PTC) on March 20, 1996.

3.3.1. Separator Samples

Table 3.3.1 reports the separator samples collected from well B-4 at Chevron's Main Pass 299 field. The separator conditions and a log of samples collected are given in Table 3.3.1.

Table 3.3.2 reports the stock tank gravity of all samples studied including those from Main Pass.

The separator gas and liquid samples were analyzed in the same fashion as the other fluids studied as part of this project. The compositional analyses of the separator gases and liquids are given in Tables 3.3.3 and 3.3.4. The usual quality checks were applied and the analyses found satisfactory.

3.3.2. Recombination

The samples were recombined per a gas-oil ratio provided by Chevron. The compositional analysis of the recombined reservoir fluid compared with the computed compositional analysis is given in Table 3.3.5. The fluid was reported to have a bubble point pressure of 998 psia at 165°F.

3.3.3. Constant Composition Expansion (CCE) Studies

The CCE studies for all fluids began with the fluids conditioned at reservoir temperature.

Tables 3.3.6 and 3.3.7 contain the CCE data at 165°F and 125°F respectively. As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscometer, both at temperature of the test. Single-phase density and viscosity measurements were taken at various pressures.

A portion of Recombined Oil 2 (Main Pass 299 well B-4) was conditioned at 1,500 psig and 165°F. The aliquot was charged into a high-pressure visual PVT cell at 40°F. The fluid was then subjected to a Constant Composition Expansion (CCE). During this expansion a bubble point pressure of 716 psia was observed.

As the CCE proceeded, fluid was also charged from the recombination cylinder to the Paar-Mettler densitometer and the capillary coil viscometer, both at 40°F. Single-phase density and viscosity measurements were taken at various pressures.

The fluid in the PVT cell was expanded down to approximately 500 psia. At 491 psia, some equilibrated gas was pumped off to the densitometer, then all remaining gas was pumped out of the PVT cell until the 491 psia equilibrated oil was all that remained in the cell. The oil phase was then pumped to the densitometer and the viscometer, while maintaining constant

temperature gas chromatographic analysis. The original oil and the oil top layer from the centrifugation were also sent for gas chromatographic analyses. A summary of the experimental data is given in Table 3.3.11.

After carefully decanting and blotting the excess oil from the centrifuge tube, 5.5 weight % of bottoms remained. A small portion looked like clay, but no attempt was made to identify or quantify this material. Nenniger found that the bottoms contained 16.4 weight % C_{22+} n-paraffins. This calculated to a solid n-paraffin in the condensate of 0.89%. When the weight % solid n-paraffin in the condensate was calculated from the difference of C_{22+} n-paraffins in the original condensate and the top layer from the centrifuge test, the value was 0.46%. The difference between 0.89% and 0.46% was larger than we found for the Main Pass or South Pelto oils. We do not know the cause of this difference, nor which value is correct. The "oil difference" value of 0.46% should be less affected by the presence of clay or water in the sample. The condensate only contained 0.5% water, so this should not have caused the problem. A plot of the n-paraffin distribution data from the two different techniques is shown in Figure 3.32. It is interesting to note that the two curves are superimposable when the "oil difference" values are multiplied by two and compared to the "solid analysis" values.

There was 5.05 weight percent of C_{17+} n-paraffins in the FSO before cooling and 4.6 weight percent after cooling. The analyses are reported in Tables 3.3.11 and 3.3.12. Paraffins were observed up to C_{86}, in the "before cooling" sample and only C_{38} in the after cooling sample. Nenniger was unable to track the n-paraffins down to the 1 ppm sensitivity threshold in the "after cooling" sample due to interference from other species present in the oil.

The n-paraffin content of the FSO #2 solids after cooling was 8.0 weight percent. The analysis is reported in Table 3.3.13. The solids showed enrichment of C_{21} through C_{77}. Paraffins below C_{21} were not reported because they are due to entrained oil in the sample. The solids show a maximum at C_{29}. If no oil/solvent was present, the deposit has a predicted melting point of 72°C.

Figure 3.3.2 compares the material balance of the original oil with the deposit and depleted oil. Figure 3.3.3 shows the difference in compositional profiles between the solid analysis and the original oil.

Appendix III: Main Pass

Index of Tables and Figures

Tables

Figures

Table 3.3.1

Main Pass 299 Well B-4
Sample Summary

Separator Gas

Cylinder Number	Separator Conditions Pressure (psig)	Separator Conditions Temperature (°F)	Laboratory Opening Pressure Pressure (psig)	Laboratory Opening Pressure Temperature (°F)
WL-205	64	61	65	69
WL-251 *	64	61	62	69
WL-253	64	61	69	70
WL-275	64	61	71	69
WL-291	64	61	62	70

Separator Liquid

Cylinder Number	Separator Conditions Pressure (psig)	Separator Conditions Temperature (°F)	Laboratory Bubble Point Conditions Pressure (psig)	Laboratory Bubble Point Conditions Temperature (°F)
WL-204	64	61	65	72
WL-207 *	64	61	77	72

* Samples selected for recombination.

Table 3.3.3

Main Pass 299 Well B-4
Separator Gas Compositions

Component	WL-205 Mol %	WL-251 Mol %	WL-253 Mol %	WL-275 Mol %	WL-291 Mol %
H2S	0.00	0.00	0.00	0.00	0.00
N2	0.75	0.76	0.76	0.76	0.76
CO2	0.11	0.12	0.13	0.12	0.12
C1	91.12	91.12	90.91	91.02	91.15
C2	4.03	4.01	4.05	4.01	4.01
C3	1.93	1.94	1.98	1.90	1.94
iC4	0.49	0.49	0.51	0.48	0.49
nC4	0.67	0.67	0.70	0.65	0.67
iC5	0.27	0.26	0.28	0.26	0.26
nC5	0.19	0.19	0.21	0.18	0.19
C6	0.19	0.19	0.21	0.21	0.19
C7	0.15	0.15	0.17	0.14	0.14
C8	0.07	0.07	0.08	0.09	0.07
C9	0.02	0.01	0.02	0.05	0.02
C10	0.01	0.01	0.01	0.03	0.01
C11	0.00	0.00	0.00	0.01	0.00
C12+	0.00	0.01	0.00	0.08	0.01
	100.00	100.00	100.00	100.00	100.00

Hydrocarbon Properties

Mol Weight	18.46	18.47	18.56	18.64	18.45
Gas Gravity	0.637	0.638	0.641	0.644	0.637
GPM Value	2.331	2.330	2.397	2.398	2.32
Z Factor at separator conditions	0.986	0.986	0.986	0.986	0.986
BTU Content per dry gas at 14.73 psia and 60°F	1121.4	1121.6	1126.3	1130.6	1120.7

Table 3.3.5

Main Pass 299 Well B-4
Hydrocarbon Analysis of Recombined Oil 2

Measured Composition

Component	Mole Percent	Weight Percent	Molecular Weight	Specific Gravity
N2	0.00	0.00	28	0.8094
CO2	0.19	0.06	44	0.8180
C1	20.43	2.35	16	0.3000
C2	1.22	0.27	30.1	0.3562
C3	1.38	0.44	44.1	0.5070
iC4	0.65	0.27	58.1	0.5629
nC4	1.05	0.44	58.1	0.5840
iC5	1.04	0.54	72.2	0.6247
nC5	2.57	1.34	72.2	0.6311
C6	2.61	1.58	84	0.7138
C7	7.49	5.18	96	0.7330
C8	9.51	7.33	107	0.7492
C9	7.78	6.78	121	0.7653
C10	6.52	6.29	134	0.7795
C11	5.03	5.32	147	0.7919
C12	4.40	5.10	161	0.8039
C13	3.82	4.81	175	0.8143
C14	3.60	4.92	190	0.8245
C15	2.89	4.29	206	0.8348
C16	2.32	3.71	222	0.8436
C17	2.09	3.58	237	0.8520
C18	1.83	3.30	251	0.8582
C19	1.48	2.81	263	0.8642
C20	1.33	2.64	275	0.8704
C21	1.10	2.30	291	0.8766
C22	0.90	1.98	305	0.8823
C23	0.84	1.93	318	0.8876
C24	0.71	1.70	331	0.8927
C25	0.68	1.69	345	0.8976
C26	0.55	1.43	359	0.9023
C27	0.51	1.36	374	0.9067
C28	0.41	1.16	388	0.9111
C29	0.42	1.22	402	0.9147
C30+	2.66	11.89	620	0.9821
	100.00	100.00		
	Properties of Hydrocarbon Fractions			
C7+ Fraction	68.86	92.72	186.9	0.8337
C11+ Fraction	37.57	67.14	248.1	0.8671
C15+ Fraction	20.74	46.99	314.5	0.8951
C20+ Fraction	10.12	29.30	401.8	0.9254
C30+ Fraction	2.66	11.89	620.2	0.9821
Overall Reservoir Fluid			138.8	0.7864
Gas Oil Ratio	157.1	scf/bbl of stock tank		

Table 3.3.7

Main Pass 299 Well B-4

Constant Composition Expansion and Property Measurements of Recombined Oil 2 @ 125°F

Pressure (psia)		Relative Volume (2)	Liquid Volume Percent	Compressibility (vol/vol x10-E06)	Oil Density (gm/cc)		Gas Density (gm/cc)		Oil Viscosity (cp)	
4034		0.9771			0.7875	*			1.164	*
3021		0.9832		6.121					1.064	*
2513		0.9864			0.7798	*			1.022	*
2008		0.9899		6.711	0.7762	*			0.906	*
1501		0.9940		8.150	0.7738	*			0.872	*
1197		0.9967		10.559	0.7722	*			0.852	*
1096		0.9978								
994		0.9991								
926	(1)	1.0000	100.00		0.7703				0.805	
893		1.0125								
842		1.0376								
741		1.1011	90.84		0.7697	*	0.0343	*	0.854	*
488		1.4105	69.80		0.7779	*	0.0258	*	0.928	*

(1) Bubble Point Pressure

(2) Relative Volume: V/Vsat is the total volume of fluid at the indicated pressure per volume of saturated fluid at the bubble point pressure.

* Measured Property Data

Table 3.3.9

Recombined Oil 2
Main Pass 299 Well B-4

Viscosity Data for Stock Tank Oil		Stock Tank Oil Density of	
Temperature °F	Viscosity cp	Temperature °F	Density gm/cc
40	14.8	60	0.8263
50	6.6	100	0.8103
60	4.2	122	0.8020
70	3.4	140	0.7944

Table 3.3.11
Main Pass 299 Recombined Reservoir Fluid
Weight Percent C17+ n-Paraffins Before Cooling

Marathon Centrifugation at 15 psia and 40°F
Cloud Point = 75°F (Cloud - Test Temp. = 35°F)
Percent Solids = 12.0
Percent n-C21+ in Solids = 8.0
Percent of Dead Oil that is solid n-C21+ at 40°F = .96 by solids analysis
Percent of Dead Oil that is solid n-C21+ at 40°F = .84 by oil difference

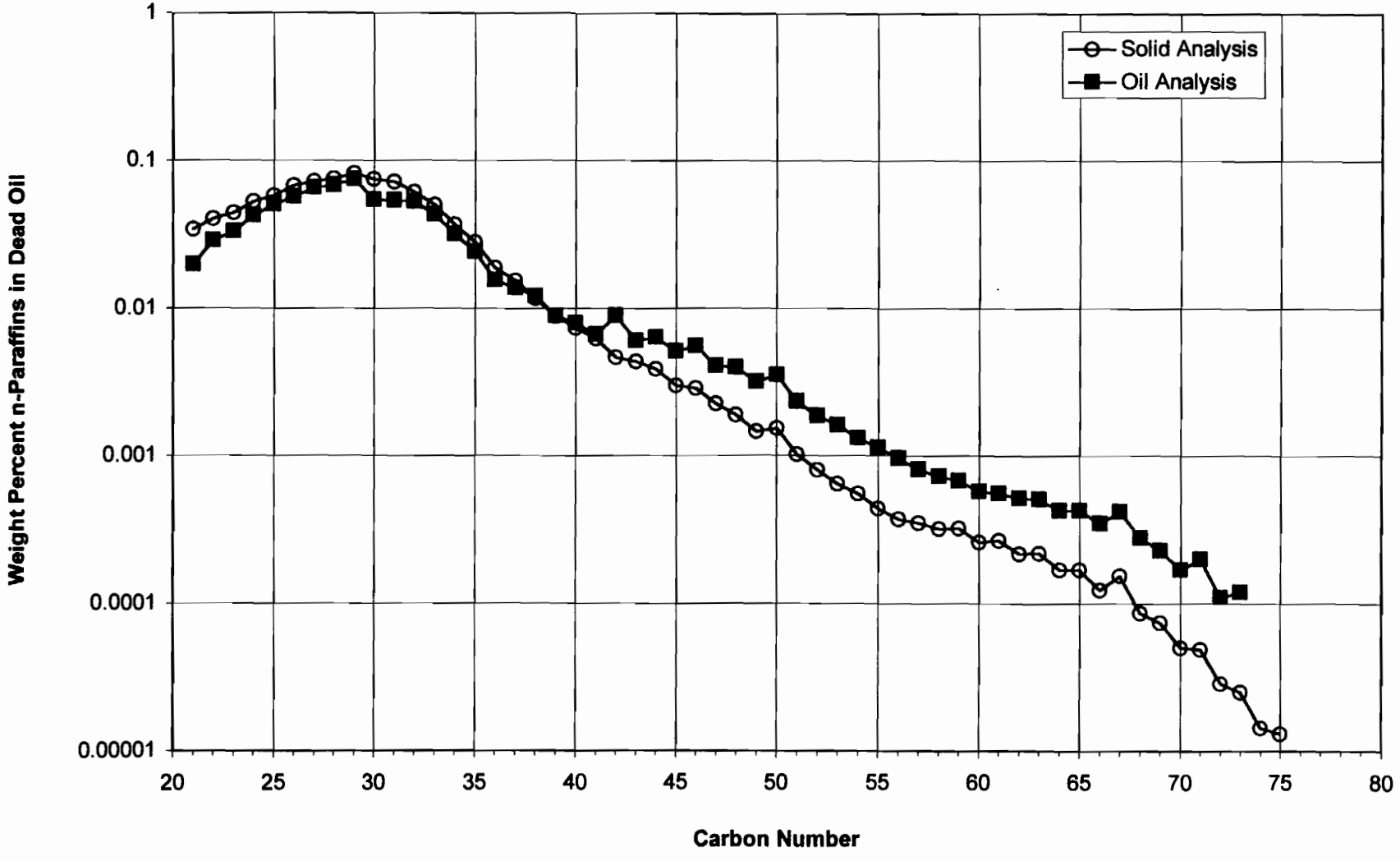
CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %	CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %
17	0.99816	19.75206	5.05345	51	0.00235	0.04654	0.01716
18	0.74463	14.73509	4.05529	52	0.00187	0.03709	0.01481
19	0.47335	9.36687	3.31066	53	0.00162	0.03212	0.01293
20	0.40952	8.10378	2.83731	54	0.00133	0.02633	0.01131
21	0.34491	6.82524	2.42779	55	0.00114	0.02255	0.00998
22	0.30599	6.05508	2.08288	56	0.00097	0.01921	0.00884
23	0.28025	5.54572	1.77689	57	0.00081	0.01607	0.00787
24	0.25736	5.09276	1.49664	58	0.00073	0.01442	0.00706
25	0.19259	3.81106	1.23928	59	0.00068	0.01342	0.00633
26	0.17619	3.48653	1.04669	60	0.00058	0.01156	0.00565
27	0.14667	2.90238	0.8705	61	0.00056	0.01115	0.00507
28	0.13161	2.60436	0.72383	62	0.00052	0.0103	0.0045
29	0.12433	2.4603	0.59222	63	0.00051	0.01011	0.00398
30	0.08595	1.70082	0.46789	64	0.00043	0.0086	0.00347
31	0.07422	1.4687	0.38194	65	0.00043	0.00842	0.00304
32	0.06442	1.27477	0.30772	66	0.00035	0.00685	0.00261
33	0.04999	0.98923	0.2433	67	0.00042	0.00822	0.00227
34	0.03551	0.70269	0.19331	68	0.00028	0.0055	0.00185
35	0.02609	0.51628	0.1578	69	0.00023	0.00456	0.00157
36	0.01689	0.33423	0.13171	70	0.00017	0.00339	0.00134
37	0.01458	0.28852	0.11482	71	0.0002	0.00402	0.00117
38	0.01263	0.24993	0.10024	72	0.00011	0.00216	0.00097
39	0.00895	0.17711	0.08761	73	0.00012	0.00228	0.00086
40	0.00796	0.15752	0.07866				
41	0.00667	0.13199	0.0707				
42	0.00894	0.17691	0.06403				
43	0.00607	0.12012	0.05509				
44	0.00636	0.12585	0.04902				
45	0.00511	0.10116	0.04266				
46	0.00555	0.10984	0.03754				
47	0.0041	0.08122	0.03199				
48	0.00399	0.07887	0.02789				
49	0.00318	0.06299	0.0239				
50	0.00356	0.07043	0.02072				

Table 3.3.13
Main Pass 299 Recombined Reservoir Fluid
Weight Percent C17+ n-Paraffins In Produced Solid

CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %	CARBON NUMBER	WEIGHT PERCENT	NORMALIZE WEIGHT %	CUMULATIVE WEIGHT %
21	0.28868	3.60974	7.99726	51	0.00859	0.10736	0.05671
22	0.33928	4.24245	7.70858	52	0.00673	0.08420	0.04812
23	0.37212	4.65309	7.36930	53	0.00541	0.06768	0.04139
24	0.44320	5.54190	6.99718	54	0.00466	0.05821	0.03598
25	0.48679	6.08696	6.55398	55	0.00369	0.04611	0.03132
26	0.56877	7.11206	6.06719	56	0.00313	0.03918	0.02763
27	0.60815	7.60448	5.49842	57	0.00295	0.03684	0.02450
28	0.63707	7.96610	4.89027	58	0.00268	0.03347	0.02155
29	0.68850	8.60920	4.25320	59	0.00270	0.03377	0.01888
30	0.62961	7.87282	3.56470	60	0.00218	0.02722	0.01618
31	0.60617	7.57972	2.93509	61	0.00223	0.02782	0.01400
32	0.51420	6.42970	2.32892	62	0.00181	0.02262	0.01177
33	0.42178	5.27406	1.81472	63	0.00184	0.02301	0.00997
34	0.31104	3.88933	1.39294	64	0.00142	0.01771	0.00813
35	0.23489	2.93713	1.08190	65	0.00141	0.01767	0.00671
36	0.15823	1.97855	0.84701	66	0.00103	0.01288	0.00530
37	0.12937	1.61768	0.68878	67	0.00129	0.01614	0.00427
38	0.09791	1.22429	0.55941	68	0.00072	0.00896	0.00298
39	0.07407	0.92619	0.46150	69	0.00062	0.00772	0.00226
40	0.06184	0.77326	0.38743	70	0.00042	0.00523	0.00164
41	0.05200	0.65022	0.32559	71	0.00041	0.00512	0.00122
42	0.03883	0.48554	0.27359	72	0.00024	0.00295	0.00081
43	0.03658	0.45741	0.23476	73	0.00021	0.00258	0.00058
44	0.03237	0.40476	0.19818	74	0.00012	0.00149	0.00037
45	0.02517	0.31476	0.16581	75	0.00011	0.00135	0.00025
46	0.02409	0.30123	0.14064				
47	0.01889	0.23618	0.11655				
48	0.01590	0.19879	0.09766				
49	0.01222	0.15286	0.08176				
50	0.01283	0.16040	0.06954				

Figure 3.3.2

Main Pass 299 Well B-4
Comparison of Solids Data by Centrifugation
Flashed Separator Oil



Appendix 3.4: Fluid Characterization and Property Evaluation – Marathon Final Report – April 1997

EXECUTIVE SUMMARY

This report and its attached Appendix present all of the data collected in response to the contract awarded to Marathon Oil Company by the University of Tulsa, Wax Joint Industry Project (JIP). These fluid characterization and property evaluation data were necessary to support the modeling and flowline studies being carried out by the JIP.

Much of this work was performed at Marathon Oil Company's Petroleum Technology Center. Data was also obtained by DB Robinson (DBR) Research Ltd. In addition, Nenniger Engineering Inc. supplied high temperature gas chromatography data.

Two black oils (South Pelto 10 Well 9-2 and Main Pass 299 Well B-4) were included in this study along with one "gas condensate" (Garden Banks 426 Well A-14). Recombinations, PVT measurements, cloud point determinations and solids studies were done by Marathon for each fluid system. DBR did some cloud point measurements and solids studies on recombined South Pelto oil and recombined Garden Banks "gas condensate." Although measurements were made under different conditions, data from Marathon and DBR were compatible. No laboratory bias was detected in the cloud point or solids formation data.

After reviewing the data and looking for trends or inconsistencies, we found the following:

Many of the PVT measurements were made above the wax cloud point, so the presence of wax crystals was not an issue. However, wax crystal effects did show up in 40°F viscosity measurements. For the Flow Loop Oil (FLO) and Flow Loop Condensate (FLC), both of which had low gas oil ratios (GOR), the capillary coil plugged so viscosity could not be measured. This was not a problem for the other fluid systems. The expected increase in viscosity due to wax crystals was observed for both black oils. Also, the change in viscosity with pressure was greater below the black oil cloud point than at higher temperatures.

Viscosity decreased with decreasing temperature for the "gas condensate." Also, the bubblepoint increased with decreasing temperature. Both effects were the opposite of observed black oil behavior.

The fluid systems characterized by this study obeyed the general correlation reported by DeepStar between stock tank oil (STO) cloud point values and the wt% C_{50+} n-paraffin. Using this correlation, the average STO cloud points were predicted to ±7°F.

Cloud points for the two black oils and the "gas condensate" showed about the same sensitivity to light ends addition. The change of cloud point with pressure was dependent

INTRODUCTION

To complete this study, many different tests were performed using a variety of fluid types generated in the laboratory. These tests and fluids were given acronyms to aid in clarification throughout the project. A list of these acronyms is presented in Table 1.

Separator and stock tank samples from three wells (South Pelto 10 Well 9-2, Main Pass 299 Well B-4, and Garden Banks 426 Well A-14) were received by Marathon Oil Company. Also, a cylinder containing a synthetic five component gas blend was made representing The University of Tulsa's natural gas stream. These field samples and the synthetic gas were used in making the various fluid systems studied in this project. A listing of these may be found in Table 2.

All tests performed for each of the fluid systems are illustrated in Tables 3a through 3c. These tests are shown in a matrix format with corresponding samples generated in the laboratory. Blocks showing a date indicate which progress report contains the data for each individual test (row) and the sample (column) used to obtain the data.

PVT DATA

PVT properties were measured at Marathon's Petroleum Technology Center. Complete data are given in the Appendix. PVT measurements were made using standard procedures and data were reviewed for consistency. With the exception of viscosity, the presence of wax solids was not expected to affect the PVT properties.

Data Consistency Check

Figure 1 is a plot of liquid volume percent versus pressure for Recombined Oil 1, Recombined Oil 2, Recombined Condensate (RC), FLO, and FLC. It should be noted that all five fluid systems including the "gas condensate" exhibited bubble point behavior, although RC was a volatile oil. The trend of higher percent liquid at lower temperatures was true for all five fluid systems. Figure 1 shows typical PVT data consistency. Density behavior was also very consistent except for RC which showed similar anomolies to those discussed in the viscosity section below.

Viscosity

A plot of the natural logarithm of viscosity versus 1/T for three of the fluids is given in Figure 2. For Recombined Oil 1 and Recombined Oil 2, the viscosity increased with a temperature decrease, but the rate of increase was different for the two fluids. Above the cloud point, viscosity of Recombined Oil 2 was less sensitive to temperature changes than Recombined Oil 1. For both fluids, low temperature viscosity was higher than would have

CLOUD POINT DATA

Three different methods were used to measure live oil cloud points. Marathon used infrared energy scattering, measured with a conventional laboratory Fourier Transform Infrared (FTIR) instrument, and filter plugging. DBR used their laser light scattering equipment. Marathon also measured cloud points for STO using the Differential Scanning Calorimetry (DSC) and Cross Polarization Microscopy (CPM) methods. Marathon measured cloud points on all of the fluid systems studied in this project as well as those previously studied for DeepStar.[1] DBR measured cloud points on recombined South Pelto 10 and Garden Banks 426 samples.

We reviewed the cloud point data to look for trends among cloud points, measurement conditions, sample types and compositions. We also looked for inconsistencies among the data. The data collected during the previous DeepStar study served as a general background for some aspects of this review.

Comments on Reported Cloud Point Data

During our review of the reported cloud point data, we found three tables that contained errors as corrected below. We also corrected these errors in the Quarterly reports copied in the Appendix.

Table 16 of the September 23, 1996 Quarterly Progress Report indicated that we obtained wax data at 2,500 and 3,500 psig using the FTIR method on the Garden Banks live separator oil (LSO) sample. The reported data were actually from the filter plugging method rather than the FTIR method.

Table 11 of the December 20, 1996 Quarterly Progress Report had errors which were repeated in Table 5 of the March 26,1997 Quarterly Progress Report. All of these errors were on Garden Banks samples. Some of these errors were simply typographical. Others were identified when analyses were repeated. The 2,212 psig pressure should read 2,500 psig. The LSO cloud point determined by filter plugging at 3,500 psig should be 88°F. The STO cloud points determined by filter plugging were 96°F at 1,000 psig, 97°F at 1,500 psig, and 98°F at 3,000 psig. The FLC cloud points determined by filter plugging were 89°F at 2,000 psig and 91°F at 3,000 psig.

We further discovered that the DSC and CPM cloud points for the two black oil STO samples had not been reported. For South Pelto STO, the DSC cloud point was 126°F and the CPM cloud point was 120°F. The DSC cloud point for Main Pass STO was 76°F, and the CPM cloud point was 79°F.

be assumed that an error of at least +/- 4°F was present.

Effect of Crude Oil n-Paraffin Composition on Dead Oil Cloud Points

Two major factors that affect crude oil cloud points are the composition of the n-paraffins in the oil and the composition of the other components in the oil which act as wax solvents. DeepStar data suggested that there might be a general correlation between the crude oil wt% C_{50+} n-paraffin content and cloud point. In Figure 4, wt% n-C_{50+} and cloud point data for South Pelto (SP), Main Pass (MP) and Garden Banks (GB) are plotted along with data for the DeepStar oils. The line in this Figure was from a least squares fit of the semi-log relationship (cloud point = 13.64ln(wt% C_{50+}) + 145.9). An average cloud point deviation of ±7°F was obtained when the equation of this line was used to calculate the 16 crude oil cloud points. The Tulsa crudes fit the same line as the DeepStar crudes. No doubt some of the scatter in Figure 4 data is due to the presence of different wax solvency effects caused by variations in crude oil composition.

Effect of Pressure and Light Ends on Crude Oil Cloud Points

DeepStar data showed that both pressure and light ends affected crude oil cloud points. Cloud point data for each fluid system studied in this project are given in the Quarterly Reports provided in the Appendix. We have plotted that data in a slightly different manner to obtain a more detailed assessment of the relationships. We used our estimates of the best cloud point values in these plots to minimize the effect of experimental error on our interpretation of the data.

South Pelto Oil

Figure 5 is a plot of cloud point values versus the amount of light ends (wt% C_1, C_2, and C_3) in the South Pelto samples. Available cloud point data obtained by Marathon are plotted for three different pressures. Data from DBR are also included. STO was assumed to be free of light ends. Light ends in FLO were added as City of Tulsa synthesized gas. Separator gas was used to obtain RIF and recombined reservoir fluid (RRF). DBR ran the RRF fluid and then flashed it at 800 psig to obtain flashed recombined reservoir fluid (FRRF). This sample had a composition that was similar to FLO but the light end source was separator gas rather than Tulsa gas.

The two DBR cloud points fit quite well with the Marathon cloud point data. For the RRF sample, the 4,000 psig DBR value is near the average of the 3,000 and 5,000 psig values. The 800 psig DBR FRRF value of 100°F was about 5 °F lower than would be expected from the 1,000 psig FLO value, but this difference was not unreasonable because there were compositional differences and two different measurement techniques were used. It is interesting that the FRRF cloud point at 800 psig was lower than the RRF cloud point at

Cloud Point Conclusions

Based on results obtained for this project and DeepStar dead oil cloud point data, there appears to be a general relationship between the natural log of the wt%C_{50+} n-paraffins in STO and STO cloud point. This correlation can be used to calculate a dead crude oil cloud point with an average deviation from a measured cloud point of ±7°F, but the actual deviation for a single crude oil may be as high as 16°F.

Cloud points measured by DBR using their laser energy scattering cell were consistent with cloud points measured by Marathon using either FTIR or filter plugging.

The change of cloud point with pressure was dependent on both crude oil "light ends" content and pressure range.

The decrease in crude oil cloud point obtained by adding a small increment of separator gas or Tulsa synthesized gas was not affected appreciably by the small differences in gas composition, but was affected by the amount of "light ends" already present in the crude oil.

The two black oils and the condensate sample show about the same sensitivity to changes in cloud point with light ends addition. In all cases, a relatively large decrease (-6 to -10°F/wt% C_1 to C_3) occurs at C_1 to C_3 concentrations less than about 3 wt%. At higher C_1 to C_3 concentrations the decrease was smaller (-3 to -0.5°F/wt% C1 to C_3).

SOLID n-PARAFFIN DATA

Two types of experiments were used to obtain solid n-paraffin data. Marathon slowly cooled dead oil from about 140°F to about 50°F below the cloud point in a sealed spinning centrifuge cell and then isolated the solids from the solids-free oil. High temperature gas chromatography was used by Nenniger Engineering to obtain a quantitative wt% n-paraffin carbon number distribution for the original oil, and the solids and solids-free oil obtained by centrifugation. Marathon determined solid precipitate amount by directly weighing the residue and from and "oil difference" method based on the difference in n-paraffin concentration of the original oil and the solids-free oil (after correcting for concentration effects due to solids loss). As shown in the Appendix, for most cases, the carbon number distribution data for the solid obtained by the "oil difference" method was very similar to that obtained by analyzing the solid directly, and the latter analysis is significantly cheaper. Values from direct analysis of the solids are used in the discussion below.

DBR cooled live oil from about 160°F to about 50°F below the cloud point in a rocking cell and used filtration to isolate the solids. The solids were then weighed and analyzed by high temperature gas chromatography to obtain a quantitative wt% n-paraffin distribution.

The black oil distribution coefficients used for our predictions were an average based on the South Pelto and Main Pass centrifugation data. South Pelto at 70°F had a TPCN of 42 and Main Pass at 40°F had a TPCN of 31, so it was necessary to place the distribution coefficient values on a comparable basis before averaging. To do this we arbitrarily set the distribution coefficient value equal to 1 for n-C_{30} for each data set. Distribution values were then averaged for each n-paraffin from n-C_{30} to n-C_{15}. The black oil distribution coefficients used for solids composition predictions are shown in Figure 10 and Table 4.

We also attempted to determine distribution coefficients for the condensate samples, but the two DBR determinations did not correct for entrapped condensate so they were significantly different from the Marathon determination and an average was not useful.

To predict the solid n-paraffin distribution at a given temperature it was first necessary to consult Figure 9 and determine the TPCN for that temperature. Once that was known, the black oil distribution coefficients were set equal to 1 at the TPCN and then the data in Table 4 were used to assign distribution coefficients to the carbon numbers below the TPCN. These distribution coefficient values were then divided into the corresponding STO individual n-paraffin concentrations to calculate the n-paraffin distribution in the solid below the TPCN.

South Pelto Solids Data

Solids data from the Marathon centrifugation test at 70°F were already discussed. The data are shown in Figure 8. The predicted solids n-paraffin distribution agrees with the measured solids distribution about as well as the STO n-paraffin distribution above the TPCN (42) agrees with the measured solids distribution. The peak in STO at n-C_{56} was not observed in the solid sample, but this was probably due to the gas chromatographic uncertainty rather than compositional differences. The same may be said for the n-C_{40} and n-C_{48} peaks in the oil. The predicted distribution was about 0.01 wt% higher than measured in the n-C_{35} to n-C_{41} range. However, this data should be of sufficient quality to check any modeling results.

The DBR South Pelto RRF filtration data at 4,000 psig and 58°F are summarized in Figure 11. The dead oil n-paraffin distribution was obtained by Nenniger, while DBR used their own gas chromatographic method to analyze the solids. The TPCN for this sample was 36. When the black oil distribution coefficients were used to predict the solids n-paraffin distribution, the results agreed quite well with the measured solids value.

DBR flashed the RRF sample at 800 psig and ran the filtration test at 50°F. The data are shown in Figure 12. The dead oil (and n-paraffin distribution) was the same as for the 4,000 psig run. The TPCN was lowered to 35 due to the lower filtration temperature. The predicted solids n-paraffin distribution was in good agreement with the measured solids values except below n-C_{31}, where the contribution from entrapped crude oil was significant.

solids n-paraffin distribution data (2 wt% solids assumed) along with the predicted solids n-paraffin distribution. In agreement with the other Garden Banks condensate solids determinations, the predicted values have too high a n-paraffin concentration for the lower molecular weight n-paraffins. This suggests the condensate distribution coefficients increase faster with decreasing carbon number than the black oil distribution coefficients indicating that condensate may be a poorer solvent for solid than black oil.

Summary of Solids Data

The n-paraffin content of precipitated solids was obtained by isolating the solids generated at a given temperature using filtration or centrifugation and then weighing and analyzing the solids for wt% n-paraffin distribution using high temperature gas chromatography. This worked quite well when the solids generation temperature was about 50°F below the cloud point and significant amounts of solids were produced. However, these tests are expensive and the amount of solids will be limited as the solids precipitation temperature approaches the cloud point.

Using the correlations developed from the data gathered in this study, it should be possible to predict the solids n-paraffin distribution directly from the wt% n-paraffin distribution of the dead crude oil.

Solids Conclusions

For a temperature range of 24 to 70°F, there was a minimum TPCN above which, all of the higher molecular weight n-paraffins, within experimental accuracy, partition to the solid phase.

The relationship between TPCN and precipitation temperature was not dependent on sample type or composition, pressure, or solids isolation technique.

Above the TPCN, the wt% n-paraffin distribution of the solid was equal to the STO wt% n-paraffin distribution.

Below the TPCN, a single set of wt% partition coefficients was used to estimate the n-paraffin distribution in the solid.

To maximize data reliability, it was desirable to have more than one technique for calculating wt% solids isolated.

DBR filtration solids data was comparable to Marathon centrifugation solids data.

Table 1

Nomenclature

The following acronyms were used in the quarterly reports and are used in the final report:

WAT	Wax Appearance Temperature
WDT	Wax Disappearance Temperature
FTIR	Fourier Transform Infrared Spectroscopy
FP	Filter Plugging
DSC	Differential Scanning Calorimetry
CPM	Cross Polarization Microscopy
CCE	Constant Composition Expansion
GOR	Gas Oil Ratio
STO	Stock Tank Oil
RIF	Recombined Intermediate Fluid (South Pelto 182 scf/bbl GOR Mixture)
FSO	Flashed Separator Oil
RRF	Recombined Reservoir Fluid
HTGC	High Temperature Gas Chromatography
FLO	Flow Loop Oil
LSO	Live Oil Separator Oil
FLC	Flow Loop Condensate
RC	Recombined Condensate
DBR	DB Robinson
FRRF	Flashed Recombined Reservoir Fluid (by DBR)
FRC	Flashed Recombined Condensate (by DBR)

Table 3a

South Pelto 10 Well 9-2 (Recombined Oil 1)

	FLUID TYPES						
Tests Performed	Sep. Gas	Sep Oil	RRF	RIF	FSO	STO	Solids
Sample Quality Checks	4/1/96	4/1/96	4/1/96	4/1/96			
Heat/Condition Samples	4/1/96	4/1/96	4/1/96	4/1/96	7/1/96	7/1/96	
Sample Compositions	4/1/96	4/1/96	4/1/96	7/1/96			
Physical Recombination			4/1/96				
Calculated WellStream			4/1/96				
CCE @ 232°F			4/1/96				
CCE @ 136°F			4/1/96				
CCE @ 42°F			4/1/96				
WAT - FTIR & Filter Plugging			7/1/96	7/1/96	7/1/96	7/1/96	
WDT - FTIR & Filter Plugging			7/1/96	7/1/96	7/1/96	7/1/96	
Cloud point - DSC						Final	
Cloud point - CPM						Final	
Solids Harvest - Centrifugation					9/23/96		
Nenninger Analyses					9/23/96		9/23/96
Viscosity at shear conditions						7/1/96	
Density - function of temp						9/23/96	
DBR Recombination			4/1/96				
DBR Data Results			Final				

Main Pass 299 Well B-4 (Recombined Oil 2)

	FLUID TYPES					
Tests Performed	Sep. Gas	Sep Oil	RRF	FSO	STO	Solids
Sample Quality Checks	7/1/96	7/1/96	7/1/96			
Heat/Condition Samples	7/1/96	7/1/96	7/1/96			
Sample Compositions	7/1/96	7/1/96	7/1/96			
Physical Recombination			7/1/96			
Calculated WellStream			7/1/96			
CCE @ 165°F			7/1/96			
CCE @ 125°F			7/1/96			
CCE @ 42°F			9/23/96			
WAT - FTIR & Filter Plugging			9/23/96	9/23/96	9/23/96	
WDT - FTIR & Filter Plugging			9/23/96	9/23/96	9/23/96	
Cloud point - DSC					Final	
Cloud point - CPM					Final	
Solids Harvest - Centrifugation				9/23/96		
Nenninger Analyses				9/23/96		9/23/96
Visc.at shear cond. (RFS)					7/1/96	
Density - function of temp					9/23/96	

Note: The date in each block denotes in which quarterly report this test data may be found.

Table 3c

Garden Banks 429 Well A-14 (Recombined Condensate)

	FLUID TYPES					
Tests Performed	**Sep Gas**	**Sep Oil**	**RC**	**FSO**	**STO**	**Solids**
Sample Quality Checks	9/23/96	9/23/96	12/20/96			
Heat/Condition Samples		9/23/96			12/20/96	
Sample Compositions	9/23/96	9/23/96	12/20/96			
Physical Recombination			12/20/96			
Calculated WellStream			12/20/96			
CCE @ 176°F			12/20/96			
CCE @ 138°F			3/26/97			
CCE @ 100°F			3/26/97			
WAT - FTIR & Filter Plugging		3/26/97				
WDT - FTIR & Filter Plugging		3/26/97				
Cloud point - DSC				12/20/96		
Cloud point - CPM				12/20/96		
Solids Harvest - Centrifugation					3/26/97	
Nenninger Analyses					3/26/97	3/26/97
DBR Recombination			9/23/96			
DBR Data Results			Final			

Note: The date in each block denotes in which quarterly report this test data may be found.

Figure 1. Change In Liquid Volume Percent During CCE

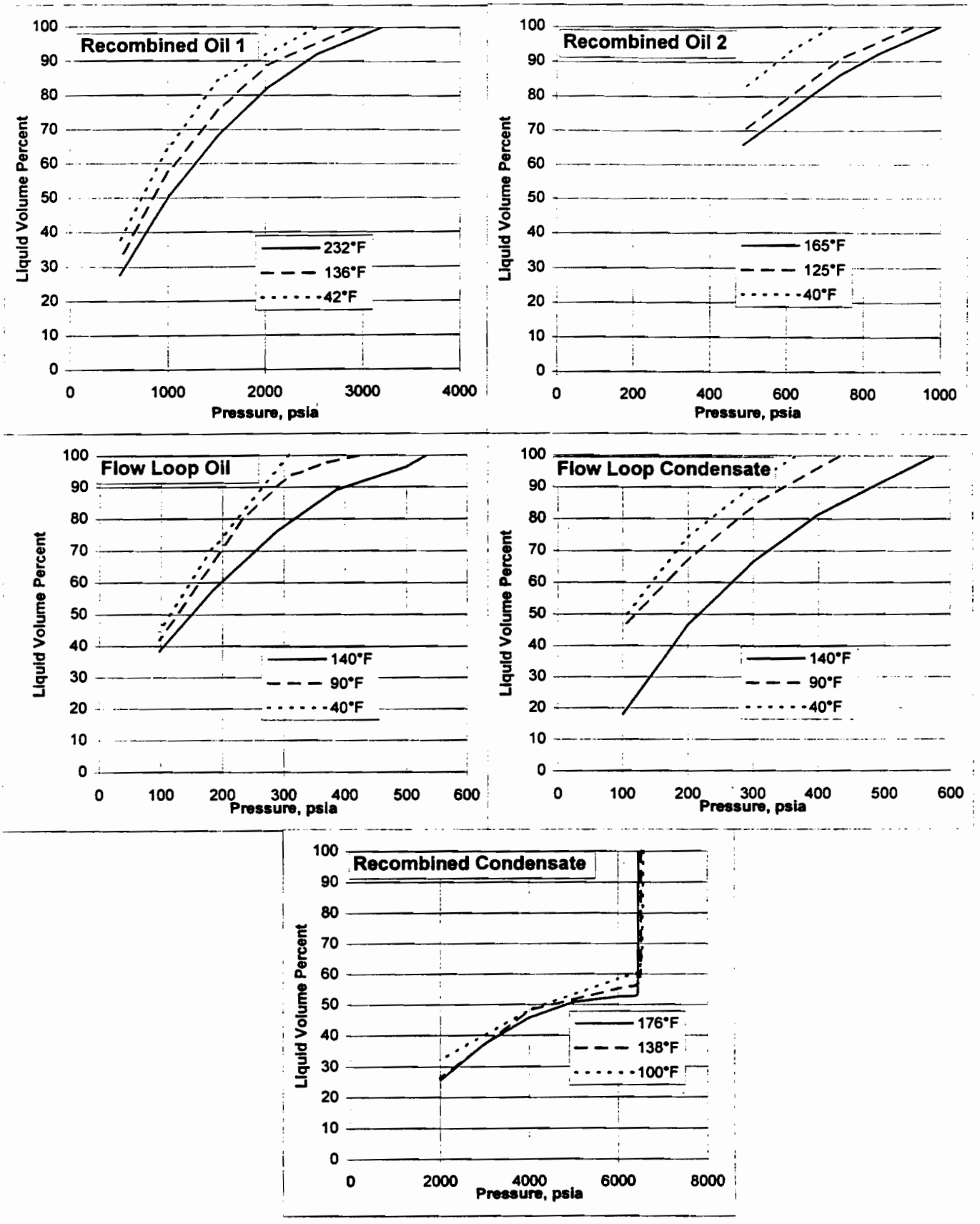


Figure 3.
Change in Viscosity With Pressure

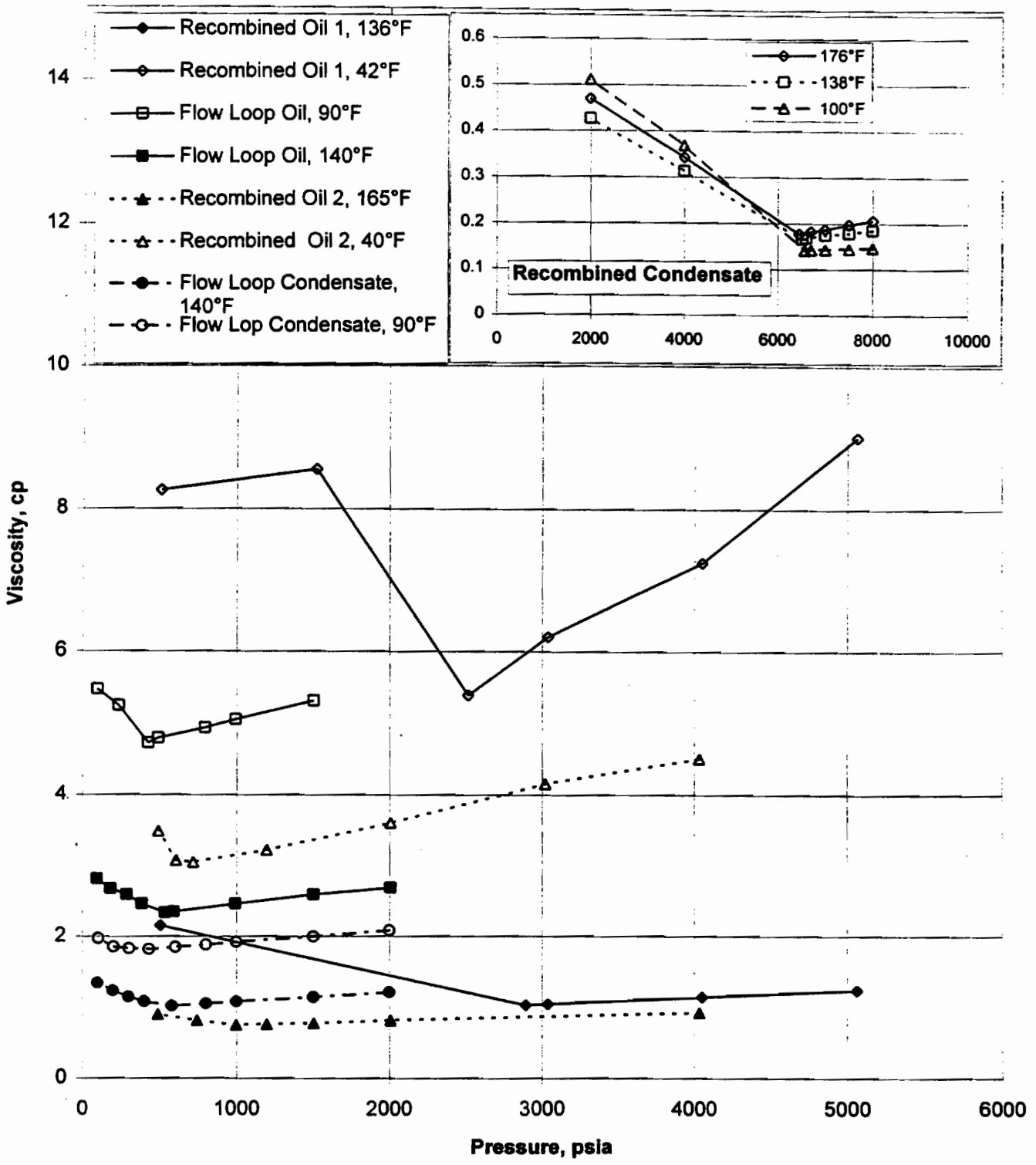


FIGURE 5. SOUTH PELTO
Cloud Point vs Wt% C1 to C3

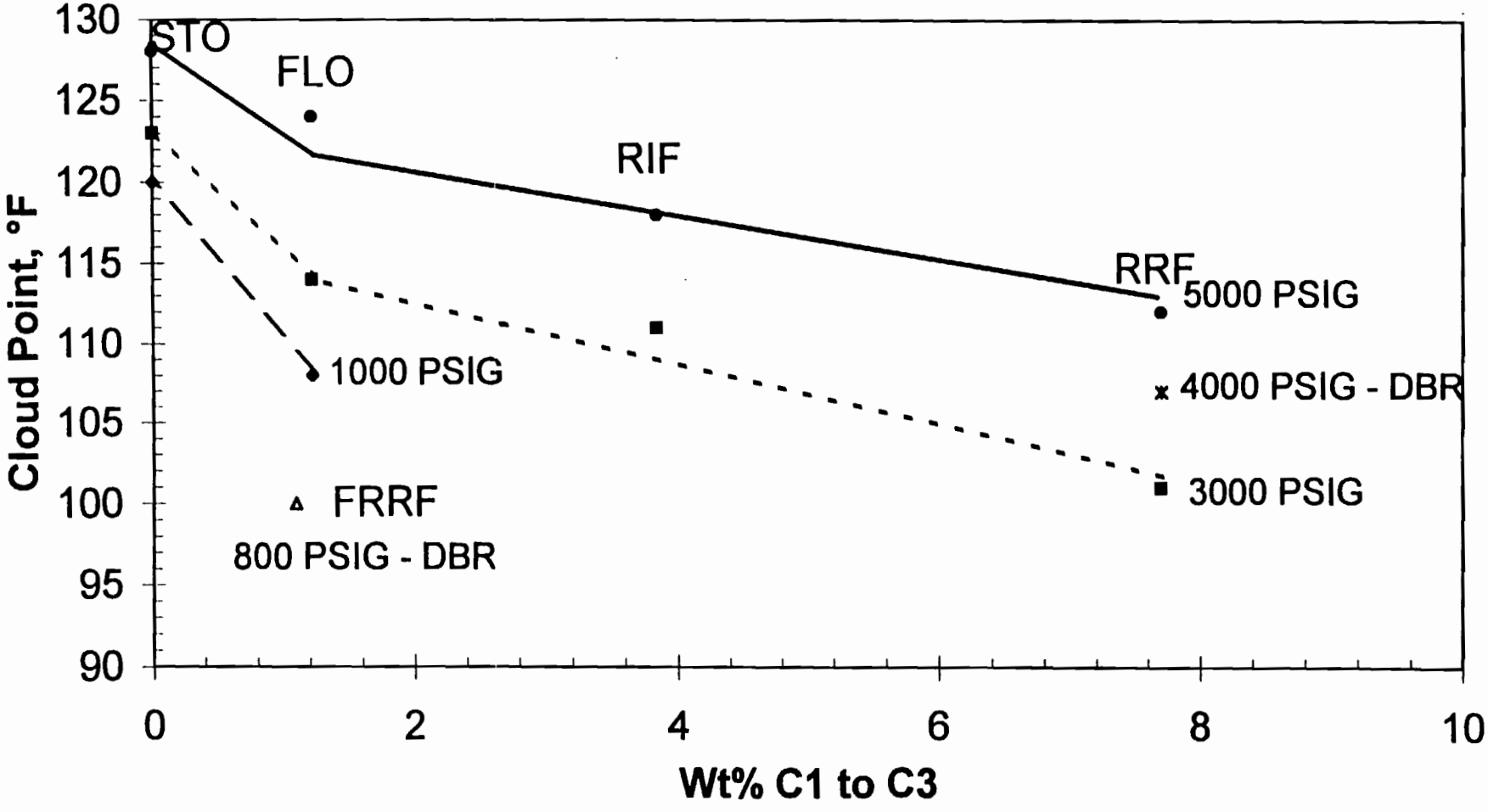


FIGURE 7. GARDEN BANKS
Cloud Point vs Wt% C1 to C3

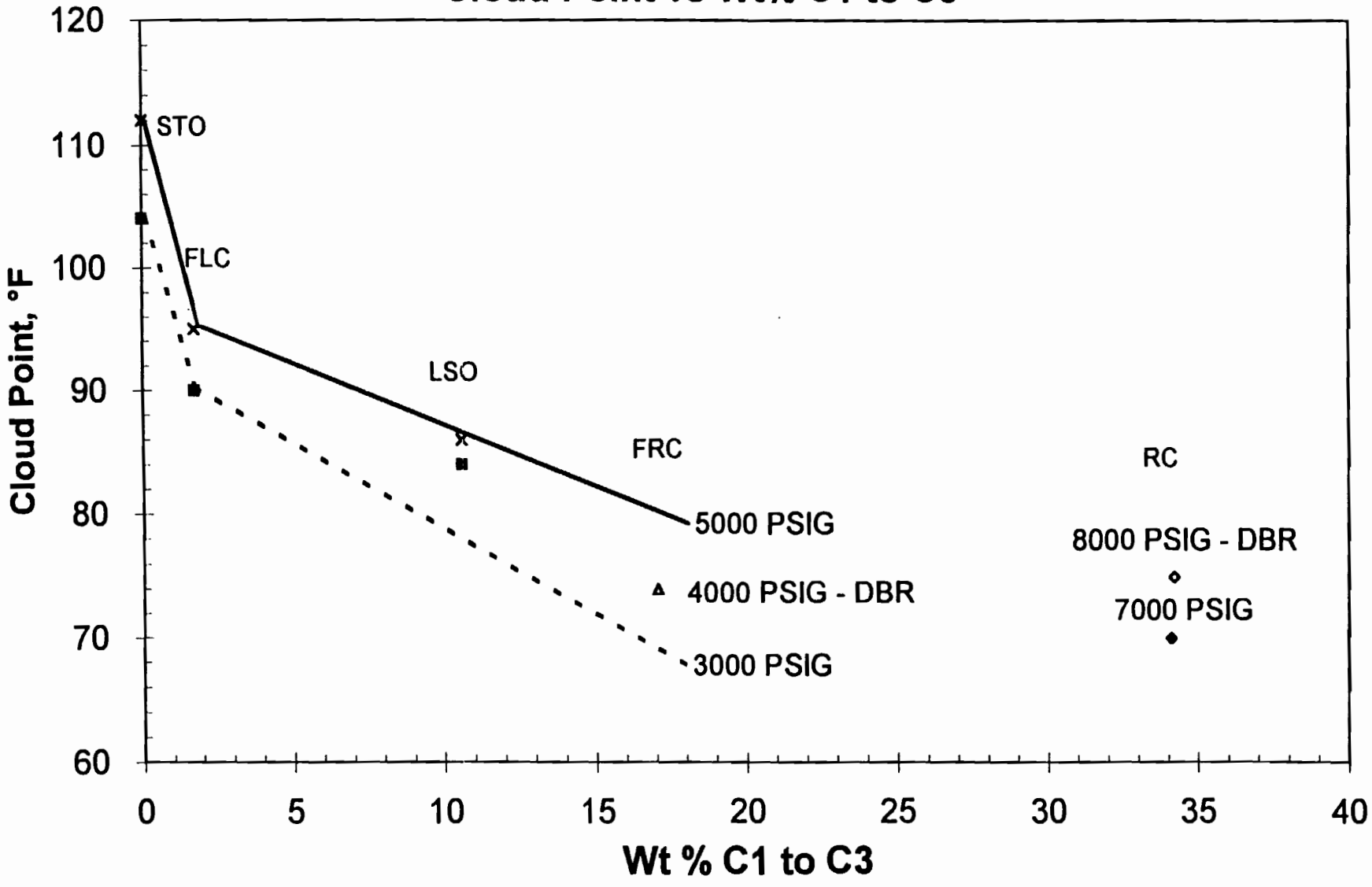


FIGURE 9. TPCN VS PRECIPITATION TEMPERATURE

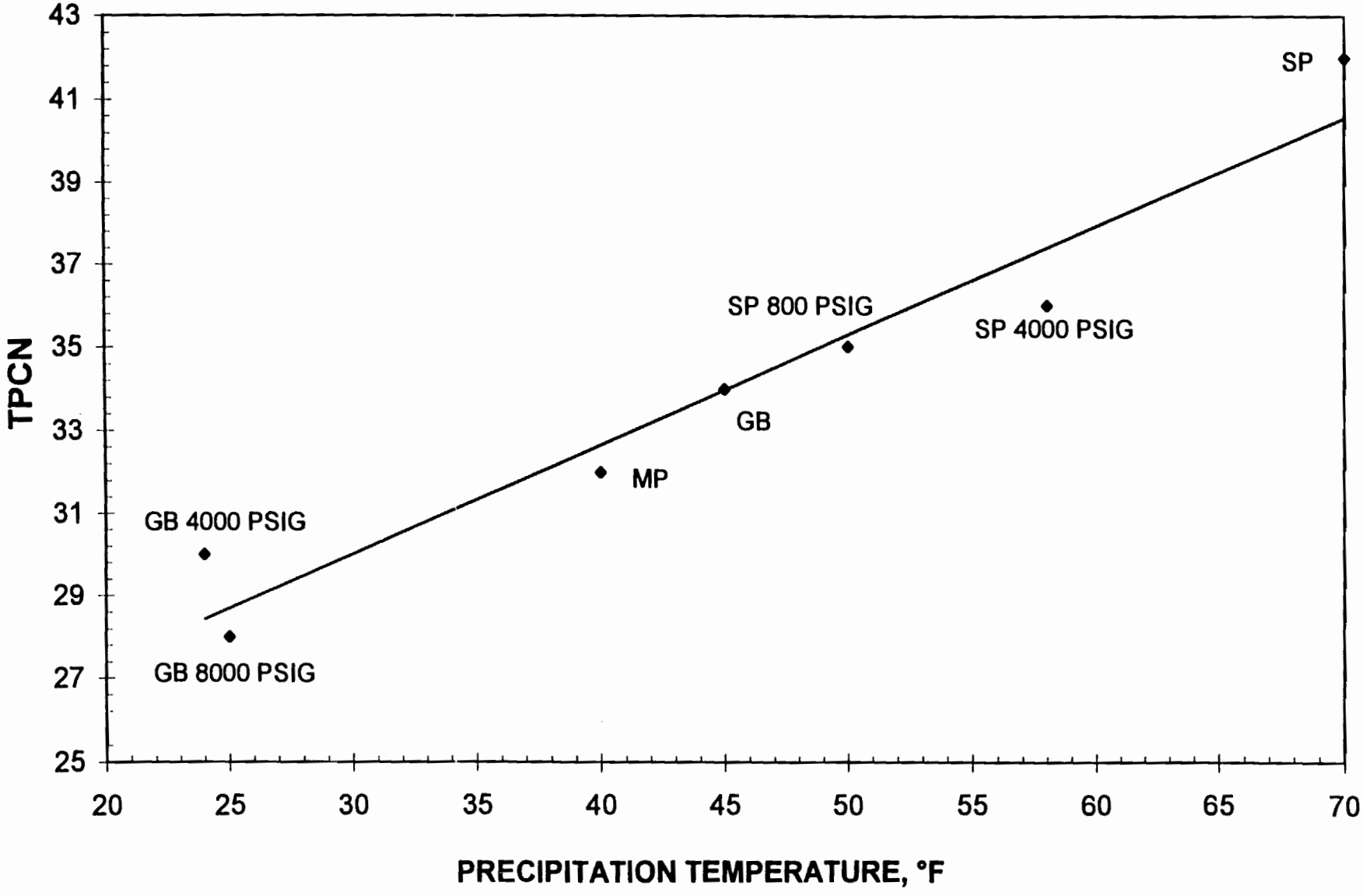


FIGURE 11. SOUTH PELTO AT 4,000 PSIG - FILTRATION AT 58°F

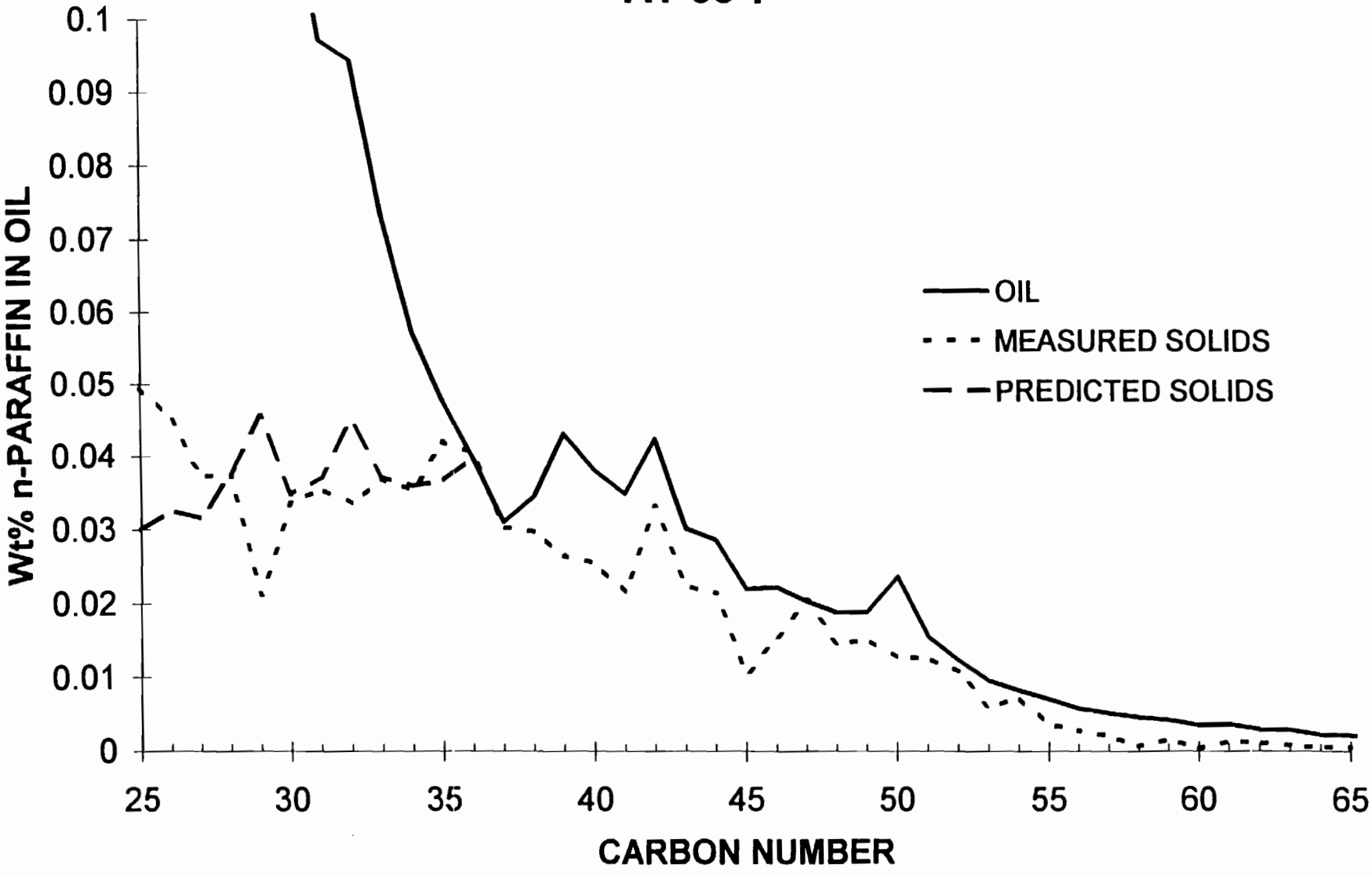


FIGURE 13. MAIN PASS CENTRIFUGATION AT 40°F

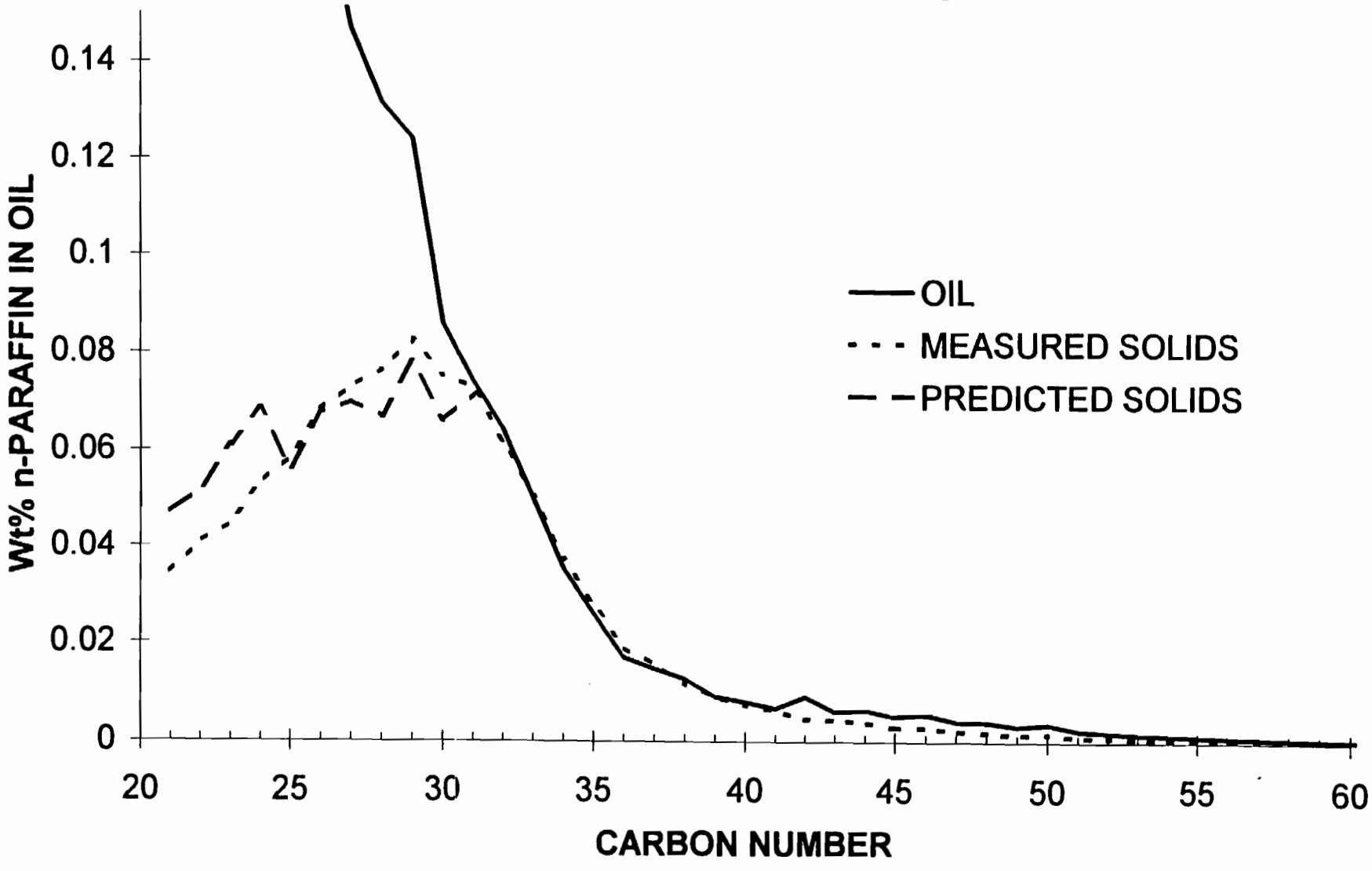


FIGURE 15. GARDEN BANKS CENTRIFUGATION AT 45°F

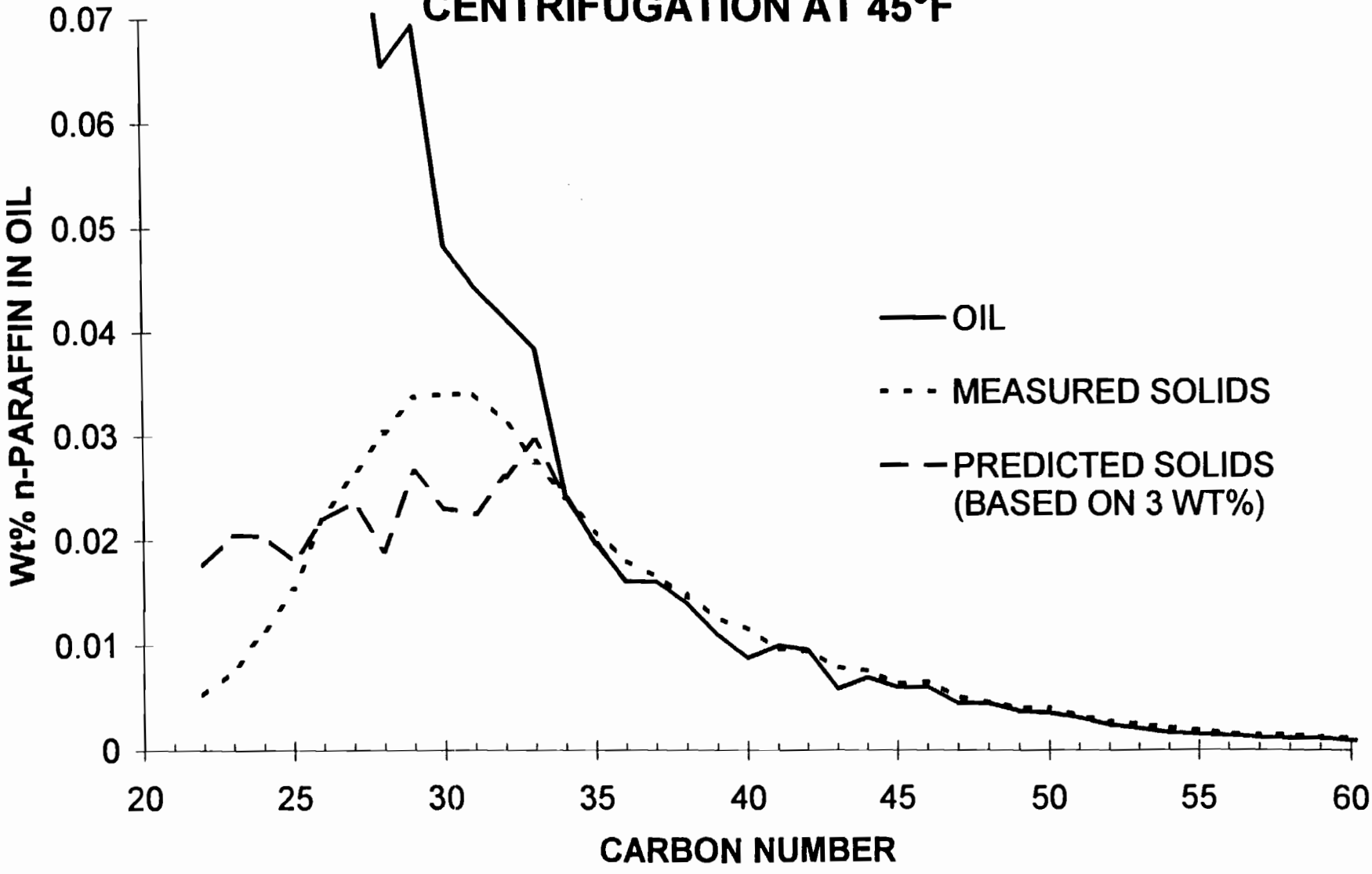


FIGURE 17. COMPARISON OF SOLIDS DATA GARDEN BANKS AT 8000 PSIG FILTRATION AT 25°F